Charles University in Prague

Faculty of Social Sciences
Institute of Economic Studies

Tatjana Vukelić

Stress Testing of the Banking Sector in Emerging Markets: A Case of the Selected Balkan Countries

MASTER THESIS

Prague 2011

Author: **Bc. Tatjana Vukelić**

Supervisor: **PhDr. Ing. Petr Jakubík, Ph.D.**

Academic Year: **2010/2011**

Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature.

The author grants to Charles University permission to reproduce and to distribute copies of this thesis document in whole or in part.

Prague, May 20, 2011

Signature

Acknowledgments

I would like to express my gratitude to Petr Jakubík from the Institute of Economic Studies, Charles University in Prague, for supervising my work on the thesis and for providing me with valuable suggestions and comments at every stage of the work.

Bibliographic Record

Vukelić Tatjana: "Stress Testing of the Banking Sector in Emerging Markets: A Case of the Selected Balkan Countries." Master Thesis. Charles University in Prague, Faculty of Social Sciences, Institute of Economic Studies, 2011, pages 120. Supervisor: PhDr. Ing. Petr Jakubík, Ph.D.

Abstract

Stress testing is a macro–prudential analytical method of assessing the financial system's resilience to adverse events. This thesis describes the methodology of the stress tests and illustrates the stress testing for credit and market risks on the real bank–by–bank data in the two Balkan countries: Croatia and Serbia. Credit risk is captured by the macroeconomic credit risk models that estimate the default rates of the corporate and the household sectors. Setting–up the framework for the countries that were not much covered in former studies and that face the limited availability of data has been the main challenge of the thesis. The outcome can help to reveal possible risks to financial stability. The methods described in the thesis can be further developed and applied to the emerging markets that suffer from the similar data limitations.

JEL Classification: E37, G21, G28
Keywords: banking, credit risk, default rate, macro stress testing, market risk

Author's e–mail: tatjana.vukelic@hotmail.com
Supervisor's e–mail: petrjakubik@seznam.cz

Abstrakt

Zátěžové testování je metoda makroekonomické analýzy, která hodnotí odolnost finančního systému proti nepříznivým událostem. Tato práce popisuje metodiku zátěžových testů a ilustruje zátěžové testování pro úvěrové a tržní riziko na skutečných datech jednotlivých bank ve dvou balkánských zemích: Chorvatsku a Srbsku. Úvěrové riziko je vyjádřené pomocí makroekonomického modelu kreditního rizika, který odhaduje míry defaultu pro podnikový sektor a sektor domácností. Hlavním úkolem práce je sestavení rámce zátěžového testování pro země, které nebyly příliš uvažovány v dřívějších studiích a pro které jsou data dostupná jen v omezené míře. Výsledek práce může pomoci odhalit možná rizika finanční stability. Metody použité v této práci mohou být dále rozvíjeny a aplikovány na rozvíjející se ekonomiky, které čelí obdobnému omezení v datech.

Klasifikace JEL: E37, G21, G28
Klíčová slova: bankovnictví, kreditní rizoko, makroekonomické zátěžové testování, míra defaultu, tržní riziko

E–mail autora: tatjana.vukelic@hotmail.com
E–mail vedoucího práce: petrjakubik@seznam.cz

Contents

List of Tables

List of Figures

Abbreviations

BCBS Basel Committee on Banking Supervision

BMI Business Monitor International

BS Banking System

CAR Capital Adequacy ratio

CB Central Bank

CDE Classified Assets of Categories C, D and E

CEBS Committee of European Banking Supervisors

CNB Croatian National Bank

CORP Corporations

CPI Consumer Price Index

EAD Exposure at Default

ECB European Central Bank

ESOP Employee Stock Ownership Plan

EU European Union

EUR Euro

Fed Federal Reserve System

FSAP Financial Sector Assessment Program

FSI Financial Soundness Indicators

FX Foreign Exchange

HH Households

HRK Croatian Kuna

IAS International Accounting Standards

IMF International Monetary Fund

KPSS Kwiatkowski–Phillips–Schmidt–Shin Test

LGD Loss Given Default

LLP Loan Loss Provision

NBS National Bank of Serbia

NPL Non–Performing Loan

OLS Ordinary Least Squares

PB Private Bank

PD Probability of Default

PPI Producer Price Index

QLR Quandt Likelihood Ratio Test

RAMSI Risk Assessment Model for Systemic Institutions

ROA Return on Assets

ROE Return on Equity

RSD Serbian Dinar

RWA Risk–weighted Assets

SCAP Supervisory Capital Assessment Program

USD United States Dollar

VaR Value at Risk

WB World Bank

Master Thesis Proposal

Author:	Bc. Tatjana Vukelić
Supervisor:	PhDr. Ing. Petr Jakubík, Ph.D.
Proposed topic:	Stress Testing of the Banking Sector in Emerging Markets: A Case of the Selected Balkan Countries

Topic characteristics Nowadays, financial stability of the banking sectors is a highly discussed topic. Especially, the assessment of the appropriate amount of capital that banks should put aside to guard against various types of risks that banks face represents a great challenge. One of the techniques that help to bring the answer to the question whether a particular bank or a banking sector have sufficient capital buffer in the case of a crisis is the stress testing.

A stress testing is a risk management tool that shows the bank's or the banking sector's financial performance under downside scenarios which are severe but still plausible. By comparing the results under these scenarios with the baseline (most likely future scenario) results and with minimum capital requirements, the banks' management and national supervisors can specify additional capital to be set aside.

In July 2010, the results of the EU–wide stress testing exercise were released. The results showed the overall EU banking sector as a resilient to particular shocks. In the light of the proceeding preparations for the EU enlargement to the Balkans this thesis focuses on vulnerabilities of four banking sectors in Bosnia and Herzegovina, Croatia, Macedonia and Serbia. The author is going to assess banking systems' performance using stress testing framework under the two scenarios: the baseline and the adverse scenario, which will be specified for each country in a conservative manner. The outcome should demonstrate whether these countries are able to withstand an economic deterioration.

Hypotheses H1: The stress testing methodology for the Balkan countries based on publicly available data can be build up.

H2: Some banks show insufficient capital adequacy under the baseline scenario.

H3: Some banks show insufficient capital adequacy under the adverse scenario.

H4: The stress testing–exercise can reveal different risks to financial stability across examined countries.

Methodology A top–down stress–testing approach will be applied. Each banking sector will be tested separately and will be roughly represented by 10 major banks (in the terms of the amount of assets compared to the total sector's assets) that operate in the country–independently of whether they are state–owned, domestic or foreign banks–and that represent at least 50% of the total sector's assets.

The baseline scenario will be either based on the Consensus Forecast and the IMF World Economic Outlook or simple VAR model will be employed. The adverse scenario will be rather the expert–based using as well the historic volatility for calibration. In particular, many parameters will be determined by expert judgement according to the unstable situations in 90's and at the beginning of the 21st century. The key macroeconomic indicators as GDP, interest rate, exchange rate etc. will be considered. One year forecast horizon will be used for both scenarios.

The regression analysis using historical data from the World Bank Database and the National Banks' databases will be used to link macroeconomic variables to micro–prudential indicators. Finally, the corresponding capital buffer will be calculated using the banking balance sheets data.

The comparison of the calculated capital adequacy for each bank and banking sector with the existing capital requirements will be made and possible threats to the financial stability will be discussed. We will further focus on the key source of risk for these countries and discuss possible policy implications.

Outline

1. Introduction
2. Related Literature
3. Theoretical Background
    - General Stress–testing Framework
    - Stress–testing Methodology Applied for the Balkan Countries

4. Empirical Analyses for the Balkan Countries
   - Macroeconomic Situation and Scenario Analysis
   - Application of Stress–testing Methodology for the Selected Countries
   - Discussion of Results and Policy Implications
5. Conclusion

Core bibliography

1. Board of Governors of the Federal Reserve System (2009a): "The Supervisory Capital Assessment Program: Design and Implementation." Federal Reserve System, Available at: http://www.federalreserve.gov.
2. Board of Governors of the Federal Reserve System (2009b): "The Supervisory Capital Assessment Program: Overview of Results." Federal Reserve System, Available at: http://www.federalreserve.gov.
3. Borio, C., C. Furfine, & P. Lowe (2001): "Procyclicality of the Financial System and Financial Stability Issues and Policy Options." *BIS Papers* **1**, Bank for International Settlements.
4. Boss, M., G. Fenz, J. Pann, C. Puhr, M. Schneider & E. Ubl (2009): "Modeling Credit Risk through the Austrian Business Cycle: An Update of the OeNB Model." *Financial Stability Report* **17**: pp. 85–101, Oesterreichische Nationalbank.
5. CEBS (2009): "Consultation Paper on Liquidity Buffers & Survival Periods." *CEBS Consultation Paper* **28**, Committee of European Banking Supervisors.
6. CEBS (2009): "CEBS Guidelines on Stress Testing." *CEBS Consultation Paper* **32**,Committee of European Banking Supervisors.
7. Čihák, M. (2007): "Introduction to Applied Stress Testing." *IMF Working Paper* **07/59**, International Monetary Fund.
8. ČNB, (2010): "Financial Stability Report 2009–2010.", Czech National Bank, Available at: http://www.cnb.cz.
9. Drehmann, M. (2008): "Stress tests: Objectives, Challenges and Modelling Choices." *Economic Review* **2**: pp. 60–91.
10. ECB (2010): "EU Stress–test Exercise. Key Messages on Methodological Issues.", European Central Bank, Available at: http://www.ecb.int.
11. ECB (2010): "EU Stress–test Exercise. Technical Note on the Macroeconomic Scenarios and Reference Risk Parameters.", European Central Bank, Available at: http://www.ecb.int.
12. ECB (2010): "Financial Stability Challenges in EU Candidate Countries–Financial Systems in the Aftermath of the Global Crisis." *ECB Occasional Paper* **115**, European Central Bank.

13. Jakubík, P. (2007): "Macroeconomic Environment and Credit Risk." *Czech Journal of Economics and Finance* **57(1–2)**: pp. 41–59.

14. Jakubík, P. & C. Schmieder (2008): "Stress Testing Credit Risk: Comparison of the Czech Republic and Germany." *FSI Award 2008 Winning Paper*, Financial Stability Institute, Bank for International Settlements.

15. Sorge, M.& K. Virolainen (2006): "A Comparative Analysis of Macro Stress–Testing Methodologies with Application to Finland." *Journal of Financial Stability* **2**: pp. 113–151.

Author Supervisor

Chapter 1

Introduction

The launch of the Financial Stability Assessment Program (FSAP) by the International Monetary Fund (IMF) and the World Bank (WB) in 1999 established the macro stress tests as part of the financial stability toolbox and brought them to the forefront of interest of the national regulators and supervisors. Moreover, in light of the recent financial crisis, the stress tests that can quantify potential impact of the adverse events on the economy are highly discussed topics. Generally, the macro stress tests measure the risk exposure of the financial system to the severe but plausible shock. In that case they can help national authorities to reveal financial system's vulnerabilities. Central banks have usually their own stress–testing models and revise them on regular basis. So far, there is no consensus on how they should be set and how the results should be interpreted. The main challenge is how to set the stress tests in order to capture reality in the most appropriate fashion. In most cases we are constrained by data availability and computation complexity.

Several studies have been already published, both theoretical and empirical ones. The surveys try to deal with the stress–testing limitations and demonstrate the application of the stress tests on the hypothetical or the real financial sectors. While financial systems of the developed countries are subjects to continuous assessment, the emerging markets has not been endowed with such an attention, yet. The emerging markets tend to be sensitive to various economic shocks. Also, the significant part of the international investments goes there, thus the assessment of their financial health is of high importance. This thesis aims to analyse the financial stability using the stress tests in the Balkan countries. Initially, we planned to assess four countries: Bosnia and Herzegovina, Croatia, Macedonia and Serbia. Being restricted by data limitations, especially by short time series that are essential for the econometric part of the study, we conduct the exercise only for the Croatian and the Serbian banking sectors.

The objective of the thesis is to investigate following hypotheses: (1) The stress tests for selected countries can be built up on the basis of publicly available data. (2) Some banks show insufficient capital adequacy under the baseline scenario. (3) Some banks show insufficient capital adequacy under the adverse scenario. (4) The stress tests can reveal risks to financial stability in the selected countries. To analyse our hypotheses we identify the relevant set of institutions that will be considered in both countries. Then, we design the baseline and the stress scenarios for the one year horizon and quantify their impact on the financial sector solvency by integrating the analysis of multiple risk factors into a probability distribution of aggregate losses. From the range of risks that can be examined we focus on the credit and the market risks. While the market risk is relatively easy to calculate, the credit risk, which is the main risk that financial institution faces, deserves a greater attention. Before the simulation of the impact of the particular stress scenario on the credit risk exposure, we usually need to link the macroeconomic variables with the relevant credit risk measures via so–called satellite models. Generally, there are two approaches how to build such model, Merton (1974) approach and Wilson (1997a,b) approach. The latter is employed in this study. We apply the aggregate results of the stress tests on the individual banks' portfolios and interpret the outcome. At the end, we calculate the potential feedback effects in terms of the fiscal costs.

The thesis is structured as follows: Chapter 2 provides an overview of related literature. Chapter 3 describes the general theoretical background of the stress tests. Chapter 4 develops the macroeconomic credit risk models for the corporate and the household sectors for each country that serve as satellite models in the stress testing. Chapter 5 consists of the specification of the scenarios and the stress–testing analysis. Chapter 6 shows the results of the stress tests on the individual banks. Chapter 7 concludes and discusses possible future research.

Chapter 2

Related Literature

In the last ten years, several studies that deal with the macro stress–testing theory or its empirical application have been published. As a part of the financial stability assessment, the macro stress tests were introduced in the FSAP 1999, joint program of the IMF and the WB (see i.e. IMF & WB 2003). After the introduction of the FSAP, national regulators and supervisors started to incorporate the stress tests into their periodical financial stability assessments. Several studies highlight the usefulness of the stress tests in the macro–prudential analysis. For example, Borio, Furfine & Lowe (2001) point out the importance of the stress tests in improving the understanding of the risk and its relationship with the business cycle. One of the largest stress–testing exercise was conducted by the legal authorities in the EU and the USA after the recent financial crisis in order to evaluate the current conditions of their financial systems (Fed 2009a,b and CEBS 2010a,b).

The discussion about the objectives, the modelling process and the challenges of the macro stress tests can be found in Drehmann (2008). Sorge & Virolainen (2006) discuss the two main approaches to the stress testing, the econometric analysis of the balance–sheet data (balance–sheet models) and the Value–at –Risk (VaR) models, applying both of them to the Finish economy. In the balance–sheet models the macro variables are linked with the balance–sheet items. The obtained coefficients are then used to simulate the impact of some shock to the system. The VaR models combine the risk factor analysis with the estimation of the distribution of loss, providing the quantification of the portfolio sensitivity to the several sources of risk. Čihák (2007) elaborated a comprehensive framework that concerns on the design of the stress tests and the scenarios, assuming the wide range of risks. He provides the illustration of possible stress–testing application to the bank's data. The paper discusses strengths and weaknesses of the several methods and provides the summarisation of the stress tests conducted by the national regulators and supervisors. Sorge (2004) provides an overview of the methodologies for the stress–testing of the financial systems, with discussion about the methodological challenges such as the measure of the endogenous risk or the correlation between the credit and the market risks. Berkowitz (2000) discusses namely the choice of the proper scenario under which the stress test is conducted.

Regarding the empirical studies, most of them consider the credit risk when they exercise the macro stress tests. Before the simulation of the impact of the stress scenario on the credit risk exposure is run, the linkage of the macroeconomic variables (GDP growth, interest rates, unemployment, industrial production, inflation etc.) with the relevant credit risk measures via the satellite models should be investigated. There are several approaches for setting up such models, usually called macro credit risk models. Drehmann (2005) and Čihák (2007) highlight, among others a non–linear relationship between the macroeconomic shocks and the credit risk in the macroeconomic credit risk models. Some studies develop the Merton–type macro credit risk models based on the modelling of the asset return in order to estimate the default rate. Merton (1974) originally designed the model to price several types of financial instruments. The idea of the Merton–type model is to define the default event as a fall of the asset return below the defined threshold. Latent–factor model of the Merton's type for the Czech economy is used in Jakubík (2007). Jakubík & Schmieder (2008) model the default rate that is measured by the inflow of the non–performing loans (NPLs). The model was applied to the household and the corporate sectors for the Czech Republic and Germany. Hamerle, Liebig & Scheule (2004) use the factor–model, based on the Basel II approach for forecasting the default probabilities of the individual borrowers in Germany. The Merton–type model is used in Drehmann (2005) for the stress testing of the corporate exposures of the banks in the UK.

Other studies follow the approach originally introduced by Wilson (1997a,b).[1] Wilson's model is one of the few models that explicitly links the default rate with the macroeconomic variables and it is base on the relatively simple logistic function that is used in the regression analysis. It was empirically shown that the non–linear logistic functions are more suitable for analysing the relationships in the model than the linear functions. Also Čihák (2007) suggests the

[1] Model known as CreditPortfolioView®, developed for McKinsey & Company.

logistic model for estimating the inputs to the stress test modelling. Wilson–type model is employed in Boss (2002) and Boss *et al.* (2006) who estimate the relationship between the macroeconomic variables and the credit risk for the corporate default rate in the Austrian banking sector. Boss *et al.* (2009) discuss the update of the Austrian National Bank's macro stress–testing model. Virolainen (2004) and Jokivuolle, Virolainen & Vähämaa (2008) develop the macroeconomic credit risk model that estimates the probability of default in various industries as the function of the macroeconomic variables for the Finish economy. Similarly, our study is based on the logistic credit risk model of the Wilson's type.

Apart from the studies discussed above, there are several other surveys that investigate the relationship between the macro variables and the banks' balance–sheet items. Babouček & Jančar (2005) employ the vector autoregression model (VAR) using the NPLs and the macroeconomic factors for the Czech Republic. Pesola (2005) investigates the macroeconomic factors that influence the banking sector's loan loss rate in the Nordic countries, Germany, Belgium, the UK, Greece and Spain using the panel–data regression on the data from early 1980's to 2002. Evjen *et al.* (2005) analyse the effects of the monetary responses to supply and demand side shocks on the banks' losses in Norway and discuss how the stress tests can be incorporated into the monetary policy decision–making. Also they present their stress–testing results in terms of the loan losses.

Some studies aim to incorporate more sources of risks into the model. One of the earlier studies is Barnhill, Papapanagiotou & Schumacher (2000). The authors measure the correlated market and credit risks and apply the results to the hypothetical South African banks, linking the changes in the financial conditions to the banks' capital ratios. Study of Van den End, Hoeberichts & Tabbae (2006) describes the multivariate scenario analysis (deterministic and stochastic) and the stress tests used by the Dutch Central Bank. The study estimates the probability of default (PD) and the loss given default (LGD) employing the logistic function, and models both the credit risk and the interest rate risk. Also Drehmann, Sorensen & Stringa (2008) estimate the integrated impact of the credit and the interest rate risks on the banks' portfolios, assessing the banks' economic value, the future earnings and the capital adequacy. They expand the analysis of the interest rate risk and the default risk on the liabilities and the off–balance sheet items. Peura & Jokivuolle (2003) measure the capital adequacy by simulating the difference between the bank's actual capital and the minimum capital requirements and they determine whether the estimated bank's capital buffer is sufficient over the business cycles. The Bank of England works on the model of the systemic risk called RAMSI (Risk Assessment Model for Systemic Institutions), which incorporates the credit risk, the interest and the non–interest income risk, the network interactions and the feedback effects. The RAMSI model tries to eliminate some of the limitations of the macro stress–testing models. Study of Aikman *et al.* (2009) discusses the introduction of the liability–side feedbacks affects in the systemic risk model and how these feedbacks can lead to higher system instability under the RAMSI model.

Chapter 3

Theoretical Background

3.1 Role of Stress Tests in the Financial Stability Analysis

Stress testing is the technique used both by banks' risk managers and financial sectors' regulators and supervisors to assess the vulnerabilities of the particular bank or the whole financial system under the severe but plausible shocks. In 1999, the Financial Sector Assessment Program (FSAP), the joint project of the IMF and the World Bank, was launched. The stress testing was included in the program. As a part of the FSAP, the stress tests have been recognised by the regulators and the supervisors as the standard tools in the financial stability analysis.

Our study concerns on the stress testing of the financial systems, commonly known as the "macro" stress testing. The macroeconomic forecasting, the early warning systems and the macro stress tests come under the financial system' toolbox for assessing the financial stability and its threats and strengths. The macroeconomic forecasting is based largely on the analyses of the historical macroeconomic data in order to project the most likely future performance of the economy. The macroeconomic forecasting models can be used also in the stress testing as a part of the scenario analysis. The early warning systems and the stress tests differ from the macroeconomic forecasting, as they focus on unlikely but plausible events. Both methods aim to generate *ex ante* warnings about the possible problems that might appear in the future. The early warning systems consist of the indicators that can help to estimate the probability of an unlikely crisis. Firstly, they define the crisis by setting up the threshold values for the relevant macroeconomic variables that have to be exceeded, and then they estimate the probability of the breakdown of the thresholds. The early warning models are usually based on the historical data. The stress testing can be based either on the historical data or on the hypothetical scenarios. It simulates some severe adverse but plausible situation in order to assess the vulnerability of the financial system under this situation. It does not analyse the probability of such crisis but its consequences for the financial stability. Detailed discussion about the monitoring systems is provided i.e. in Sahajwala & Van den Bergh (2000). The following chapter aims to provide the theoretical background of the stress–testing methods.

3.2 Building Blocks of Stress–testing Models

The macro stress tests measure the risk exposure of the financial institutions (or the selected group of financial institutions) to unlikely stress events. Their goal is to help the regulators and the supervisors to identify system vulnerabilities and overall risk exposures that can lead to the problems with the financial stability. The macro stress–testing framework can be described as follows: Firstly, we assume some shock to the economy. Using the macroeconomic model we link the shock to the macroeconomic variables such as GDP, interest rates, inflation etc.[1] The assumed macroeconomic variables are then linked to the banks' balance–sheet data through the satellite models. Then, we map the effect of the shock into the banks'financial performance and we estimate the possible impacts in terms of i.e. minimum capital adequacy ratio (CAR)

Formally, the stress–testing models can be written as follows (see Sorge 2004, pp. 3–4):

$$\Omega\left(\tilde{Y}_{t+1}/\tilde{X}_{t+1} \geq \bar{X}\right) = f(X^t, Z^t) \tag{3.1}$$

where X^t is the set of past realisations of the macroeconomic variables X, Z^t is the set of past realisations of the other relevant factors, $\tilde{Y}_{t+1}$ is the measure of distress for the financial system, $\tilde{X}_{t+1} \geq \bar{X}$ is the condition for stress test scenario to occur, $\tilde{Y}_{t+1}/\tilde{X}_{t+1} \geq \bar{X}$ is the uncertain future realisation of a measure of distress in the event of the shock, $\Omega(.)$ is the risk metric used to compare financial system vulnerability across institutions and scenarios and

[1] Sometimes, the macroeconomic models are not available. In that case we can employ vector autoregression (VAR) or vector error correction models or we can simply use the historical observations during the periods of the distress or we can expertly judge the movements of the macro variables.

$f(.)$ is the loss function that maps the initial set of shocks to the final impact measured on the financial sector's portfolio. It links the changes in the macro variables and the overall financial distress.

The starting point when we model the stress tests is to define the scope of the analysis (objectives, set of institutions or portfolios to be analysed, exposures and risk measures and data–generating process). The exposures are given by the set of exogenous systematic risk factors. The data–generating process of systematic risk factors finds the interdependences among these factors and across the time. Accordingly, the impact of the factors on the risk measure of the exposures is captured. The stress–testing scenarios are applied when the model is set up. After designing and calibrating the scenario we estimate the direct impact of the scenario on the balance–sheet items. The new approaches try to evaluate the possible feedback effects both on the financial system and the real economy (i.e. in terms of fiscal costs).

3.2.1 Bottom–up vs. Top–down Approach

There are two approaches how to set up the macroeconomic stress tests. In the bottom–up macro stress tests, the supervisor (i.e. central bank) sets the assumptions about the future economic conditions for the stress tests and approves the individual bank's internal models and other assumptions for running the test. The stress test itself is conducted by the banks and the supervisor collects the results afterwards. In the top–down approach, the supervisor not only sets up the conditions but also conducts the stress test, applying the same assumptions, procedures and models on all banks.[2].

As an example of the bottom–up approach is the recent stress–testing exercise of the Fed (2009a,b). The banks were provided with the basic assumptions and their internal methods were subject to the approval of the Fed. Nevertheless, the banks themselves conducted the exercise and provided the supervisor with the results, which were then summarised and published. The top–down approach can be found i.e. in Sorge & Virolainen (2006). Some central banks use the combination of both approaches, for example the Dutch Central Bank (see Van den End, Hoeberichts & Tabbae 2006).

The top–down and the bottom–up approaches have their pros and cons. The main advantage of the top–down approach is that the same assumptions and models are applied to all banks, which allow for the comparison. Also, the

[2]See Čihák (2007) and Jakubík & Sutton (2011).

network linkages can be captured. The disadvantage of the top–down approach is that conducting the stress tests on the system's level can lead to the loss of some relevant information, being this confidential or too complex to be captured by the supervisor. The bottom–up approach can capture complexities better and usually does not suffer from the data limitations because the detailed data on the individual debtors are available in the banks. The disadvantage is that the individual banks' results need not to be comparable as the banks possess the certain level of freedom in choosing the models and the methods in the exercise. Also the supervisor might not be able to control the consistent implementing of the assumptions that were provided, especially in the large financial systems. Moreover, the summarisation of the individual banks' outcomes can neglect the important interdependencies among the institutions.

3.2.2 Objectives

Drehmann (2008) identifies three main objectives of the stress tests: (1) the validation–to assess the risks and the portfolio's vulnerabilities, (2) the decision making–the test results can help in the business decisions and planning, and (3) the communication–the results can describe the overall situation in the financial institution or the whole sector and can be presented to the target audience. As Drehmann argues, the objectives are essential for designing the models. If our main target is to validate the situation and to make decision according to results of the model, this model should be accurate and with the good forecasting performance (the use of robust econometric techniques and structural models might be appropriate). But if we run the model and we want to present the results to the public, which may not be involved in the process, the model and its results should be transparent, easy to understand and tractable (reduced–form models are more appropriate).

Before the model is set, the group of relevant financial institutions, which we want to analyse, should be defined. Capturing the whole financial sector is more comprehensive, but usually very difficult as it is a complex task. Modellers frequently choose the large banking institutions that are relevant for the stability of the system. Sometimes, the distinction between the state–owned, the private and the foreign banks is done (see Čihák 2007). The banks can be grouped by their size (large, medium–sized or small banks) or performance (strong banks and weak banks). Next step is to define the relevant portfolio for measuring the risk exposures (trading books or banking books). Sometimes the data limitations lead to the creation of the hypothetical portfolios that simulate the distribution of assets and risk exposures. Some models distinguish the exposures by the debtor's classes (consumer loans, interbank loans, corporate loans further divided by industrial sectors), see for example Boss (2002), Sorge & Virolainen (2006) or Jakubík & Schmieder (2008).

3.2.3 Exposures

The objectives of the stress test determine the choice of exposures. Ideally, the model would capture the whole financial system and would assess its most important risks. Given the data and the model limitations (the models are able to capture the real world only in a reduced form) this task is difficult to accomplish. Usually, we choose only the part of the system and we make simplifying assumptions in order to create the model and run the test. The common approach is to test the banking system because it usually counts for the major part of the financial system, and as Drehmann (2008, p. 67) argues *"because of its pivotal role in the transformation of savings into investments and, hence, its position in transmitting financial system shocks back to the real economy"*. Some authors test also the other sectors of the financial system. For discussion about the modelling of the insurance and the pension sectors see Čihák (2007).

The major part of the stress–testing models copes with the risk within the national system. Stress testing of the single financial system benefits from better data availability, and can provide the implications for the monetary policy decision–making. Some studies focus on the international macro stress–testing models. Pesaran *et al.* (2006) developed the model where the asset values of the credit portfolio are linked to the dynamic global macro model.

Table 3.1 summarises the risks to which the financial institutions can be exposed. So far, the majority of studies focused on the credit risk (Drehmann 2005, Pesaran *et al.* 2006 or Jakubík & Schmieder 2008). However, some authors try to incorporate more risks into the stress–testing model. Drehmann *et al.* (2008) incorporate the credit and the interest rate risks and estimate their impact on the banking system. Čihák (2007) runs the stress–testing model to assess the vulnerabilities of the hypothetical banking system, using several risks, which have been analysed separately. Nevertheless, for the more realistic forecasting the correlation of the risk factors should be evaluated. The measures of the correlated market and credit risks can be found in Barnhill,

Table 3.1: Risks modelled in the stress testing

Credit risk	The creditor's risk of losses arising from the borrower's failure to meet his obligations defined by the contract.
Market risk	The risk of losses in balance sheet (and off–balance sheet) positions arising from the movements in market prices (stock prices, interest rates, foreign exchange rates, commodity prices).
Liquidity risk	The risk that an institution will be unable to meet its obligations when they fall due without experiencing significant losses or to sell position without losses because of insufficient market depth.
Contagion risk	The risk that the failure of one or more institutions will negatively affect financial performance of other institutions.
Concentration risk	The risk of losses arising from the uneven distribution of exposures to an institution's debtors (or to sectors, products etc.).

Source: CEBS (2009b) and Čihák (2007).

Papapanagiotou & Schumacher (2000) or Van den End, Hoeberichts & Tabbae (2006).

So far, the stress tests focused mainly on the asset side of the balance sheet. The liabilities side is, however, essential for modelling the liquidity risk (maturity mismatch between the assets and the liabilities can cause serious problems with the liquidity for the bank) and for analysing net interest income. Similarly, the off–balance sheet positions are important when calculating exchange rate risk losses.

3.2.4 Risk Measures

The assessment of the risks to the financial sector can be done through the simple indicators, i.e. the Financial Soundness Indicators (FSIs), or through the stress testing.[3]. The FSIs are based on the balance–sheet and the income–statement data, the information about the ownership structure and the linkages between the institutions (for example, non–performing loans (NPLs), loan loss

[3] Čihák (2007) considers also the individual banks' z–scores, which are directly linked to the probability of banks' insolvency.

provisions (LLPs), return on assets (ROA), return on equity (ROE), net open positions in foreign exchange etc.). The FSIs provide the overall picture of the soundness of the banks and the financial sectors. The overview of the financial soundness indicators, as were defined by the International Monetary Fund (IMF), is provided in Table A.1 and A.2 in Appendix A. Table A.1 shows the core FSIs. They cover only the banking sector and are essential to assess its financial stability. Table A.2 summarises the additional FSIs that cover data on the other financial institutions and the relevant market participants (households, real estate sector, non–bank financial sector, corporate sector etc.). Each FSI measures the financial system sensitivity to the specific risk factor (liquidity risk, market risk etc.). In order to assess all system vulnerabilities it should be appropriate to analyse several FSIs and also the inter–relationships among them.[4]

The choice of the risk measures is determined by the objectives of the stress testing and the considered exposures. Moreover, the variables used as the measures of the impact of the stress tests are subjects to data limitations. According to Čihák (2007), the risk measure should fit two requirements: (1) the possibility to interpret the variable as the measure of the financial system's health, and (2) the credible linkage of the variable to the risk factors. Čihák (2007) also provides the overview of the risk measures commonly used in the stress testing. We will discuss some of them briefly. The list described below is incomplete as it provides only a few indicators. For more indicators such as the net interest income, the z–scores or the market–based indicators we refer to Čihák (2007).

Capital, capitalisation and capital injection The use of capital as a measure of effect of the shock is an instinctive approach, arising from the fact that the impact on solvency results in the changes in capital. The advantage is that data on capital are usually publicly available for the financial institutions in developed as well as in developing countries. The disadvantage is that the result is provided as a number and it might be necessary to compare it to some other variable in order to assess the impact of the shock. One of the possibilities is to divide capital by the assets or the risk–weighted assets (RWA). The advantage of the capital adequacy ratio is that it is the commonly accepted indicator of the financial health. Another option is to divide the capital by some macroeconomic factor (i.e. GDP). Such indicator provides direct link to the macroeconomy. In

[4] For detailed discussion about the FSIs, see IMF (2006).

our study we use this indicator as a measure of potential fiscal costs from the banks' failure under the shock.

Profits and profitability During the "good" times, banks usually create profits. In the case of distress, the profits can serve as the first buffer against losses before the capital is employed. Accordingly, it could be useful to express the shock in terms of capital and profits. The disadvantage when estimating the profits is that often we do not know, what amount of profit would the banks keep and what amount would distribute. That results in the approximation of profits by the past values or some other indicators. The measure scaled by bank's size (i.e. return on equity or return on assets) allows for the comparison among the institutions.

Ratings and probabilities of default the ratings and the probabilities of default (PDs) allow for combining the solvency and the liquidity risks into a single measure. The indicators are useful as they translated the changes in variables into the changes in ratings and if we link ratings with PDs, the impact of shock on the PDs can be estimated.

The banks set the capital against all risks that they face (credit, market, operational, business risk etc.). Yet, not all of them are included in the stress–testing model. The indicated capital buffer can be too large since it goes to all risks but the model considers that it is spent only on the analysed risks. The aggregation of variables is a problematic issue, too. Testing the aggregate capital adequacy of the financial system may not reveal significant vulnerabilities concerning the individual institutions and the whole system. The use of the size–weighted average can help to assess the risks properly (the insolvency of a small bank is not alarming for the system as a whole while the big insolvent players can cause serious system instability through the contagion effect and can become subjects to policy actions).[5]

In the stress tests we assume that the market agents are passive when the shock occurs. That means that we assume they do not change their behaviour in the light of the crisis. In reality this is not usually valid. In order to maintain this assumption as realistic as possible we should think carefully about the time horizon over which the stress tests will be run. The integration of the endogenous behaviour of the market participants and the policy makers into

[5]Drehmann (2008, pp. 69–70).

the model is one of the greatest challenges for the stress–testing development. We discuss it in detail in Section 3.5.

3.3 Stress–testing Scenario

Another challenge in the stress–testing model is the choice of the scenario. The adverse scenario should be severe enough to uncover the risks to financial stability but still plausible. The selected shock can be the univariate shock in the single risk factor, such as the decline in equity prices. The shock can be also multivariate, reflecting the change in the various risk factors. The multivariate scenarios are often more realistic because they allow for the interaction of the variables. According to Berkowitz (2000) there are four types of scenarios (the list developed for the models that focus on assessing the robustness of capital):

1) Scenario that simulate the shocks which we believe are more likely to happen than the observed historical data suggest;

2) Scenario that works with shocks which have never occurred;

3) Scenario that simulate the shocks which represents the possibility of a breakdown of statistical patterns under some circumstances (structural breaks of the states of the world);

4) Scenario that simulate the shocks that express some structural breaks, which can occur in the future (i.e. the change of the exchange rate regime).

Čihák (2007) distinguishes between two ways how to design the consistent scenario. The first way is the "worst case" approach that answer the question which scenario has the worst impact on the financial system, with the given level of plausibility. Alternatively, there is the "threshold approach", which for a given impact on the system answers what is the most plausible scenario that would lead to that impact. Level of plausibility can be set according to historical observations. Alternatively, scenarios can be drawn from the data–generating process or some variables can be set expertly.

The extreme historical events are easy to communicate and to implement. Under the historical scenarios we could estimate the behaviour of the market participants more properly, because their behaviour could be similar to that observed in the past. Also, the historical scenarios are severe but plausible, as they have already happened in the past. Another, and direct, option that utilise the historical data is to plot the observed risk factors against the measure of the financial health of the system (i.e. CAR, NPLs) and to pick the most adverse combination of the risk factors. This method can, however, lack the consistency as the identified most stressful observations can be from the completely different historical periods. The main disadvantage of using the historical scenarios is that it is uncertain that the same situations would repeat in the future.

For developing scenario through the data–generating process, Drehmann (2008) identifies four main methods that can be employed: (1) the calibrated distributions of the unobserved factors, (2) the autoregressive processes for each underlying macro variable, (3) the reduced form vector autoregressive macro models, and (4) the structural macro models. Specifically, for the communication purposes the macro models are more suitable than the modelling of the unobservable factor. The macro models can show the important macroeconomic transmission channels but can be relatively complex, tool. In turn, the autoregressive models do not include the interdependences of the systemic risk factors but, as Van den End, Hoeberichts & Tabbae (2006, p. 3) argue, do not provide for the economic foundation structure of the scenario. The choice of the model depends on the objectives of the stress test and on the systematic risk factors that are assumed.

3.4 Review of the Methodological Approaches to Macro Stress Testing

The methodology discussed in this section concerns on the top–down approach to the stress testing. Sorge (2004) and Sorge & Virolainen (2006) distinguish between the two methodological approaches how the macro stress tests can be modelled. The first is the "piecewise approach" that considers the balance–sheet models. These models analyse the direct link between the banks' accounting items (NPLs, LLPs etc.) that measure their vulnerability and the business cycle (GDP growth, unemployment etc.). Secondly, there is the "integrated approach" that applies the Value–at–Risk (VaR) models. In the VaR models the multiple risk factors are combined into the mark–to–market probability distribution of losses that the financial system could face under the individual scenario.

The balance–sheet models are widely used in the stress tests. The estimated coefficients can be employed to simulate the impact of the macro shock on

Table 3.2: Schematic classification of the macro stress–testing methodologies.

Model	Balance–sheet model	Value–at–Risk model
Function	Exploring the link between the banks' accounting measures of vulnerability and the business cycle	Combining the analysis of multiple risk factors into a mark–to–market portfolio loss distribution
Main modelling options	Time series or panel data	Wilson (1997a,b) macro–econometric risk models
	Reduced–form or structural models	Merton (1974) micro–structural risk models
Pros	Intuitive and with low computational burden	Integrates analysis of market and credit risks
	Broader characterisation of stress scenario	Simulates shift in entire loss distribution driven by the impact of macroeconomic shocks on individual risk components
	Monetary policy trade–offs	Has been applied to capture non–linear effects of macro shocks on credit risk
Cons	Mostly linear functional forms have been used	Non–additivity of VaR measures across institutions
	Parameter instability over longer horizons	Most models so far have focused on credit risk only, usually limited to a short–term horizon
	Loan loss provisions and non–performing loans may be noisy indicators of credit risk	Available studies have not dealt with feedback effects or parameter instability over a longer horizon
	No feedback effects	

Source: Table adopted from Sorge & Virolainen (2006, p. 118).

the financial sector. The balance–sheet models can be either the structural models or the reduced–form models. The VaR models are relatively complex and combine the multiple risk factors (credit risk, market risk etc.). Table 3.2 shows the schematic classification of the both types of models. Both approaches are discussed in this section, in line with the studies of Sorge (2004) and Sorge & Virolainen (2006).

3.4.1 Balance–sheet Models

The balance–sheet models are based on the estimation of the sensitivity of the balance sheets to the adverse change in the crucial macroeconomic variables. The estimated coefficients are used to simulate the impact of the hypothetical scenarios on the financial system. For the balance–sheet models, the Equation 3.1 can be re–written as follows:

$$\Omega\left(\tilde{Y}_{i,t+1}/\tilde{X}_{t+1} \geq \bar{X}\right) = f(X^t, Z_i^t) \tag{3.2}$$

where i is the individual portfolio, $\tilde{Y}_{i,t+1}$ is the measure of distress for the portfolio i in time $t+1$ (loan loss provisions, nonperforming loans or write–offs), $\tilde{X}_{t+1} \geq \bar{X}$ is the condition for the stress–testing scenario to occur, $\tilde{Y}_{i,t+1}/\tilde{X}_{t+1} \geq \bar{X}$ is the uncertain future realisation of the measure of distress in the event of the shock, $\Omega(.)$ is the risk metric used to forecast the measure of the distress (Y) under the assumptions given by the condition $\tilde{X}_{t+1} \geq \bar{X}$ and $f(.)$ is the function of the past realisations of the vector X of the relevant macro variables (GDP, inflation, interest rates or degree of indebtedness etc.) and the vector Z of the exogenous bank–specific variables (bank size, capitalization or cost–efficiency). It links the changes in the macro and the bank–specific variables and the portfolio's distress.[6]

The balance–sheet models can be the models that estimate Equation 3.2 in the reduced form, using either the time–series or the panel data methods, or the economy–wide structural models. Both of them link the vulnerability of the system (bank losses) to the changing macro variables.[7] The advantage of the balance–sheet models is that they are intuitive and easy to implement. On the other hand, they are usually expressed in the linear form, although the relationship between the banks' risks and the macro variables is rather non–

[6] Sorge & Virolainen (2006, pp. 117–119)
[7] Sorge & Virolainen (2006, p. 119).

linear.[8] Moreover, they frequently investigate the expected losses and do not consider the whole loss distribution. We provide a brief discussion about the each type of the balance–sheet model.

Time series models The time series models are suitable for assessing the concentration of the system portfolio's vulnerabilities over time. The most common measures are the NPLs, the LLPs or the composite indices of the balance–sheet and the market variables. The loan loss provisions or other variables can be linked to the macro indicators such as the GDP, the output gap, the unemployment, the inflation, the income, the consumption and the investment, or the interest and the exchange rates. As an example, for the stress–testing of the Austrian banking sector, Kalirai & Scheicher (2002) analyse the aggregate LLPs as the functions of the set of macro variables using the time series model.

Panel data models The panel data models analyse the individual banks' portfolios or the aggregate banking systems across the countries, evaluating the role of the bank–specific or the country–specific risk factors. Again, the dependent variables could be the LLPs, the NPLs or the indicators of profitability. The dependent variables are often not only the functions of the macroeconomic variables but also of the bank–specific factors (size, portfolio diversification, specific clients etc.). The cross–sectional dimension enables to evaluate the impact of the shock on the banks' health according to their specific characteristics (size or clients' orientation). Pesola (2005) investigates the macroeconomic factors that influence the banking sector's loan loss rate in the Nordic countries, Germany, Belgium, the UK, Greece and Spain using the panel–data regression.

Structural macro models The structural macro models are able to capture the complex relationships in the stress testing, and thus can better show the correlation between the shock and the relevant macro variables or the structural interdependences. Some authors tried to incorporate the reduced–form Equation 3.2 in the central banks' structural macro models. Hoggarth & Whitley (2003) analyse the impact of the liquidation rates on the write–off rates through the reduced–form model, whereas the shock to the macroeconomy was analysed by the macroeconomic model and the structural model linked the macro factors to the liquidation rates afterwards. De Bandt & Oung (2004) have developed

[8] For example, Drehmann (2005) found that the systematic factors have non–linear and non–symmetric impact on the credit risk.

the similar model for France. Some authors combine the micro and the macro models. In Evjen *et al.* (2005) the micro models are used to estimate the individual firms' probability of default that is based on the actual balance–sheet data (operating income, interest expenses, long–term debt etc.) and the company size or the industry characteristics. The proxies for the debt–servicing capacity of the corporate sector are used to estimate the banks' loan losses. The overall model then estimates the impact of the demand and the supply shock in the banking system.

3.4.2 Value–at–risk Models

The VaR macro models represent the extension of the VaR models adopted in the financial institutions. The models are based on the estimation of the conditional probability distribution of losses for the different stress scenarios. The value at risk then, as the summary statistic of this distribution, measures the sensitivity of the portfolio to the different risks. The macro VaR models can be set as follows:

$$VaR_{i,t}\left(\tilde{Y}_{i,t+1}/\tilde{X}_{t+1} \geq \bar{X}\right) = f(E_{i,t}(X_t); P_t(X_t); PD_t(X_t); LGD_t(X_t); \Sigma_t(X_t)) \tag{3.3}$$

$$X_t = h\left(X_{t-1}, ..., X_{t-p}\right) + \epsilon_t \tag{3.4}$$

where the portfolio of the aggregate banking system is given by the vector of the credit and the market risk exposures E , the vector of the prices P, the default probabilities PD, the loss given default LGD and the matrix of the default volatilities and the correlations Σ. Furthermore, X is the vector of the macroeconomic variables which evolve over time, shown in Equation 3.4. The function $f(.)$ maps the overall vulnerability of the system into the probability distribution of losses conditional on the macro scenario denoted as $\Omega\left(\tilde{Y}_{i,t+1}/\tilde{X}_{t+1} \geq \bar{X}\right)$.

The VaR approach allows for the non–linear relationships between the macro variables and the indicators of the financial stability. Also, it allows for the integration of the credit and the market risk into one model. The shortcoming of the VaR models is the non–additivity across the portfolios when the models are applied to the individual banks.[9] Thus, for the analysis of the banking system, the aggregated portfolio is usually used. However, running the model on the aggregate portfolio might neglect the contagion effect that could occur among the institutions.

For the VaR models, Sorge & Virolainen (2006) highlight two approaches that explicitly link the default probabilities to the macro variables. Wilson (1997a,b) approach allows to model directly the sensitivity of the default probabilities to the evolution of the set of the macro variables. Merton (1974) approach firstly models the response of the equity prices to the macro variables and then translates the asset price changes into the probabilities of default.

Merton (1974) approach Merton's model was originally developed for the firm 's level. After him, the approach was extended for the purposes of the macro stress–testing. Merton's models are frequently set as follows: Firstly, we make some assumptions about the joint evolution of the macro and the market factors. These factors are then linked to the corporate return on equity through the multi–factor regression on the panel of firms. Finally, the equity returns enter the model to estimate the individual firms' probabilities of default. Merton–type model for the Czech economy was used in Jakubík (2007). Jakubík & Schmieder (2008) apply the model on the household and the corporate sectors for the Czech Republic and Germany. Hamerle, Liebig & Scheule (2004) use factor–model to forecast the default probabilities of the individual borrowers in Germany. Merton's model was used also in Drehmann (2005) for the stress testing the corporate exposures of the banks in the UK.

Wilson (1997) approach Wilson's approach consists of modelling the relationship between the default rate and the macro variables. Accordingly, we generate the shocks and simulate the evolution of the default rates, which are at the end applied to the particular credit portfolio. Wilson's approach is intuitive and not computationally demanding as the Merton–type models. Wilson's logistic model was used in studies of Boss (2002) and Virolainen (2004). Boss (2002) and Boss *et al.* (2006) estimate the relationship between the macroeconomic variables and the credit risk for the corporate default rate in the Austrian banking sector. Virolainen (2004) and Virolainen, Jokivuolle & Vähämaa

[9] The VaR of the banks' consolidated portfolio does not equal to the sum of the individual banks' VaRs due to the correlations among them.

(2008) develop the macroeconomic credit risk model that estimates the probability of default in the various Finish industries.

Integrated market and credit risk analysis Changes in the macroeconomic fundamentals can influence the market value of banks' assets and liabilities directly but also indirectly. Indirectly, they affect the indebtedness ratios of the households and the firms, which change the credit risk exposures of the banks. Sorge & Virolainen (2006, p. 127) argue that the incorporation of the macro variables in the credit risk models implicate that these models analyse both the market and the credit risks. Wilson's and Merton's models implicitly incorporate the credit and the market risks. There are studies which try to reflect the two risks more explicitly, for example Barnhill, Papapanagiotou & Schumacher (2000). Their findings indicate that the market risk, the credit risk, the portfolio concentration, and the asset and liability mismatches are all important but not additive sources of risk. Accordingly, they should be evaluated as a set of the correlated risks.

3.5 Limitations and Challenges

The stress testing, as the relatively new technique, faces many limitations and challenges. The main shortcomings of the macro stress tests are the frequent data limitations, the inability of models to capture the correlation of risks and the risk measures over time and across institutions and to interpret the results in longer time horizon. Next, the endogenous behaviour of the market agents and the macro feedbacks, the forecasting limitations of the reduced–form models and the computational problems of the structural models. Last but not least, the incorporation of the model's implications in the policy decision–making is only partial. The complex discussion of the limitations and the challenges of the current stress tests can be found in Sorge & Virolainen (2006), Čihák (2007) or Drehmann (2008).

3.5.1 Data Availability and Time Horizon

The data that are essential for the stress testing are limited in several ways. First of all, the severe historical shocks are rare. The historical data are of limited use. Frequently, the adjustment of the model by the additional assumptions that are set by the expert judgment or based on the data–generating process is needed. Secondly, the financial markets develop rapidly and it is difficult to track all the changes. The financial institutions' data are often not available (at least for public use). Some of them (i.e. data on the individual clients) can be confidential. Even the provided data need not to be exact or comparable with the data from the other institutions. The model can break down during the shock as some characteristics, observed in the past, can change (i.e. the borrowers' repayment discipline). The data limitations should be taken into account when setting–up and running the models. The use of the standard parametric econometric models with the insufficient data leads to the non–robust estimates and the large errors, which in turn reduce the forecasting ability of the model.

Regarding the time horizon, there exist the trade–off between the predictive power of the model and the ability of the shock to fully translates into the deterioration of the banks' financial performance. The crisis usually evolves over the time and it takes even a few years to show its whole impact. But when considering longer time horizon, the problems with the endogenous responses of the system emerge. It is not unlikely, that bank would take the steps to decrease losses if they once recognise the crisis, even though if its impact did not fully emerge.

3.5.2 Endogeneity of Risk

Drehmann (2008) provides the three reasons why the endogeneity of the risk emerges in the stress testing. It happens because of (1) the endogenous behaviour of the market agents, (2) the liquidity risk, and (3) the macro feedbacks. The endogeneity of risk causes that the impact of the exogenous shocks can be disproportional. The endogenous behaviour of the agents shows that they are not passive when the shock occurs. For example the banks can fight against the losses that arise from the crisis by hedging or realigning the portfolio when some assets or liabilities mature. The liquidity risk (defined in Table 3.1) may emerge as the response of the endogenous behaviour in the market (i.e. the run on the weakly performing banks in the case of panic on the market).

Macro feedbacks reflect the linkages between the real economy and the financial sector. In the stress test we assume the impact of the macroeconomy on the financial system (often called as the first round effect). The second round effect is the impact of the stressed financial sector on the macroeconomy. The difficulties with the macro feedbacks arise from their complexity due to the heterogeneous market agents that respond differently on the stimulations.

Frequently, the second round effect is expressed as the injection needed to bring the particular banks to the regulatory minimum requirements (i.e. CAR). The injection needed does not cover all feedback effects but it is the useful tool how to assess the potential fiscal costs of the distress.

Chapter 4

Macroeconomic Credit Risk Model

4.1 Theoretical Framework

The credit risk model developed in this study is based on the approach originally introduced by Wilson (1997a,b). Wilson's model is one of the few models that explicitly links the default rate with the macroeconomic variables and it is based on the relatively simple logistic function that is used in the regression analysis. It was empirically shown that the non–linear logistic function is more suitable for analysing the relationships in the model than the linear functions. Wilson's model was further used in the Boss (2002) or Virolainen (2004). Also Čihák (2007) suggests the logistic model for estimating the inputs to the stress–testing modelling. We will discuss the model briefly, however, for the more detailed discussion, we refer to Wilson (1997a,b).

The idea of the macro credit risk model is as follows: We assess the credit risk, which is expressed by the default rate, in dependence on the macroeconomic variables.[1] We simulate the future default losses according to the changing macroeconomic situations. We test the macroeconomic variables for the possible correlations in order to reveal existing interdependences. The outcome of the model is used as the basis for the macro stress testing in Chapter 5.

The default rate or the default probability, defined as the portion of "bad" loans to total loans in the banking system, is in our model shown as the ratio of non–performing loans (NPLs) to total loans (NPL ratio). The default rate is regressed against various macroeconomic variables in order to estimate their impact on the aggregate banking sector portfolio. We run the model for the

[1] We assume that more than one variable affects the dependent variable, thus we can call the model as the multi–factor model.

household and the corporate sectors separately in order to detect the specific factors that influence the credit risk in these two sectors.[2] We do not consider the lending to the government sector, since it is commonly considered that this type of lending does not carry any default risk.

Our model estimates the sector–specific default rate using the logistic function of the sector–specific index, which depends on the values of the macroeconomic variables:

$$npl_{s,t} = \frac{1}{1 + e^{-y_{s,t}}} \tag{4.1}$$

which can be re–written as:

$$ln\left(\frac{npl_{s,t}}{1 - npl_{s,t}}\right) = y_{s,t} \tag{4.2}$$

where $npl_{s,t}$ denotes the NPL ratio (default rate) of the sector s and $y_{s,t}$ the sector–specific index of the sector s at time t. Contrary to Virolainen (2004), but in line with Boss (2002), we adopt the formulation of the sector–specific index in such a way that the lower value of $y_{s,t}$ implies the better state of the economy with lower default rate $npl_{s,t}$.[3]

The index $y_{s,t}$ represents the overall state of the economy, and it is the linear function of the exogenous macroeconomic factors:

$$y_{s,t} = \alpha_s + \beta_s x_{s,t} + \epsilon_{s,t} \tag{4.3}$$

where α_s is the intercept, $\beta_s = (\beta_{s,1}, \beta_{s,2}, ..., \beta_{s,n})$ is the set of the regression coefficients related to the set of sector s–specific macro explanatory variables $x_{s,t} = (x_{s,1,t}, x_{s,2,t}, ..., x_{s,n,t})$, and $\epsilon_{s,t}$ is the random error, which is assumed to be independent and identically distributed $\epsilon_{s,t} \sim N(0, \sigma^2_\epsilon)$.[4]

[2]The separation of the credit risk modelling for the household and the corporate sector was used i.e. in Jakubík Schmieder (2008). Some authors run the model on the individual industrial sectors, see Virolainen (2004).

[3]The formulation leads to the negative coefficients for the variables to which the NPLs ratio is inversely proportional (i.e. GDP growth) and the positive coefficients for the variables to which the NPLs ratio is directly proportional (i.e. interest rate).

[4]Some authors further model the development of the time series of the individual macroeconomic factors as the set of the univariate autoregressive equations of the second order AR (2):

$$x_{j,t} = c_{j,0} + c_{j,1}x_{j,t-1} + c_{j,2}x_{j,t-2} + \nu_{j,t}$$

where $c_j = (c_{j,0}, c_{j,1}, c_{j,2}$ is the set of the regression coefficients related to the j–th macroeconomic factor, and $\nu_{j,t}$ is the random error assumed to be independent and identically distributed $\nu_{j,t} \sim N(0, \sigma^2_\nu)$ (see Boss 2002 or Virolainen 2004). The purpose of the model is

The model described above is suitable for the stress testing as it respects the empirically demonstrated fact that the probability of default is higher in the "bad"times and lower in the "good"times. Moreover, it separates the corporate and the household sectors, which usually react to the macroeconomic shocks in the different ways.

4.2 Data

Our credit risk model is based on the quarterly data. The dependent variable in the model is the ratio of banking sector's non–performing loans (NPLs) to total loans (default rate) with respect to the sector to which it refers (either corporate sector or households).[5] The explanatory variable is the sector–specific index, composed of the various macroeconomic variables. The macroeconomic data are the quarterly data, defined as the percentage change in the actual value compared to the corresponding period of the previous year, thus derived on the year–to–year basis.[6] The time series that were used were generally reported in the National Banks' or Statistical Offices' databases and publications.

4.2.1 Croatia

The quarterly macro data for Croatia are based on the rate of growth in the given quarter relative to the corresponding quarter of the previous year. They were obtained from Croatian National Bank (CNB)[7], National Statistical Office[8] and Eurostat[9]. Namely, for the corporate sector the macro factors include: 1) the real GDP growth rate in Croatia and in the EU 15[10], 2) the growth rate of the nominal and the real effective exchange rates, 3) the growth rate of

to estimate the macro variables's future values, which are applied to the credit risk model. We do not consider the macro variables's modelling as we obtain the projected values from the economic forecasts (i.e. Consensus Forecast) in the case of the baseline scenario, and from the historical volatility analysis for the adverse scenario. Moreover, we did not find the macroeconomic factors that are considered in our model to follow the AR (2) process.

[5]It would be more convenient to use as the dependent variable the first difference of the NPLs. However, given the logistic form of the credit risk model, such variable would show the negative values, which are not allowed for the logistic function.

[6]Note that data that are not derived on the annual basis should be seasonally adjusted before the analysis starts.

[7]Available at: http://www.hnb.hr

[8]Available at: http://www.dzs.hr

[9]Available at: http://epp.eurostat.ec.europa.eu

[10]The EU 15 is composed of: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom. We prefer to use this composition of the EU in order to avoid changes in the time

the nominal HRK/USD and HRK/EUR exchange rates, 4) the growth rate of the nominal and the real short–term and long–term lending interest rates for the corporate loans, 5) the inflation measured by the Consumer Price Index (CPI)[11], and 6) the growth rate of the interest rate spread[12].

For the household sector in Croatia we consider the following macro determinants: 1) the real domestic GDP growth rate, 2) the growth rate of the nominal and the real effective exchange rates, 3) the growth rate of the nominal HRK/USD and HRK/EUR exchange rates, 4) the growth rate of the nominal and the real short–term and long–term lending interest rates for the household loans, 5) the inflation measured by the CPI, 6) the growth rate of the unemployment rate [13], 7) the real wage growth rate, and 8) the disposable income growth rate. The credit risk model for the corporate and the household sector in Croatia has been estimated using the observations from Q1 2000 to Q2 2010 (42 observation sample).

The dependent variable in the Croatian credit risk model is the quarterly default rate measured by the ratio of NPLs to total loans in the particular sector (firms or households). The data on the NPLs has been available only on the aggregate basis, apart from the annual rates in the period 2006–2010. These observations were split into the total, the corporate and the household NPLs. We calculated the average ratio of sectoral NPLs to total NPLs and we applied the derived coefficients on the NPLs from the rest of the sample period in order to generate the time series of both the corporate and the household NPLs from Q1 2000 to Q2 2010. Then, we calculated the sectoral NPL ratios by comparing the sectoral NPLs to the corresponding sector's total loans.

Figure 4.1 shows the development of the total and the sectoral default rates over the sample period. The NPL ratio (default rate) reaches the relatively elevated values of around 18% during the years 2000 and 2001. According to our estimations, in the same period the households show the higher rates

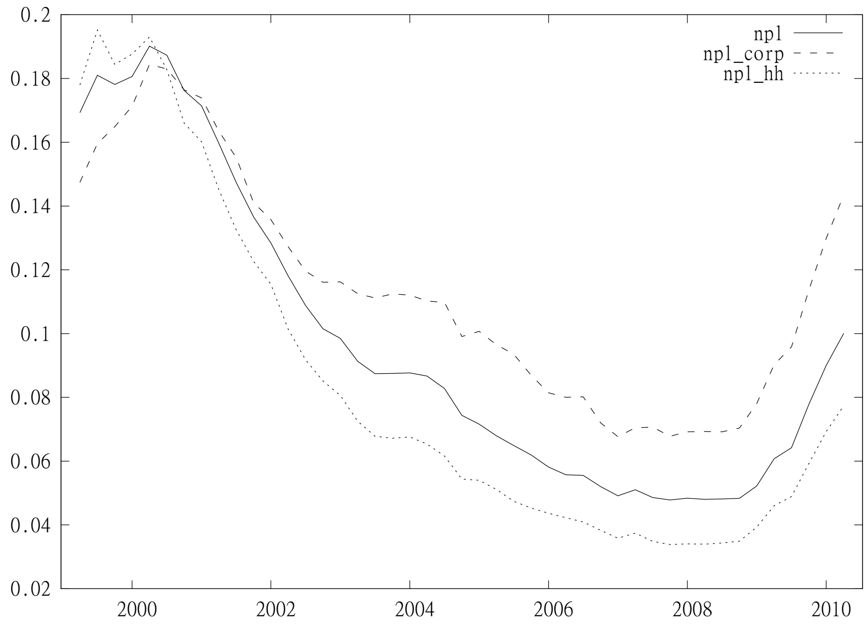
series due to the enlargements of the EU. The real GDP growth rate of the EU is considered due to the large foreign trade between Croatia and the EU.

[11] Accordingly, the CPI was employed in the calculations of the real values of the particular macroeconomic variables such as the effective exchange rate or the interest rates.

[12] The interest rate spread is defined as the difference between the interest rates on total loans and on total deposits.

[13] The calculation of the unemployment rate is based on the definition of the unemployment rate provided by the International Labour Organization (ILO) (the unemployment rate is the number of unemployed persons as the percentage of the labour force, see http://www.ilo.org). For the period 1999–2001 only the annual unemployment rate was available. Assuming the equally distributed inflow of the labour force and the unemployed over the year, we linearly interpolated the annual data in order to obtain the quarterly growths.

Figure 4.1: Total NPL ratio and estimated NPL ratios for the corporate and the household sectors in Croatia.



Source: Author's computations. Variables *npl*, *npl_corp* and *npl_hh* represent total NPL ratio, corporate NPL ratio and household NPL ratio, respectively.

than the companies. This differs from the commonly observed pattern. The demonstrated values suggest that at the beginning of the 21st century, even though the corporate loans accounted for the major part of the total loans, the repayment discipline of the Croatian households might have been lower than that of the companies. In the following year, however, the trend has changed and the corporate default rate outranked the household rate. Accordingly, the default rates began to descend and they reached their minimum in the year 2008 (the default rates of 6.8% for the corporations and 3.4% for the households). The trend has changed when the financial crisis emerged in the late 2008. All rates jumped up, and their increasing tendency is noticeable until the end of the sample period with 2010 values of 14% and 8% for the corporations and the households, respectively.

4.2.2 Serbia

In the case of Serbia, we used the National Bank of Serbia's (NBS's) on–line database to generate the macroeconomic data, except for the GDP growth rate in the EU 15.[14] In line with the existing literature, we consider the following

[14] Available at: http://www.nbs.rs

variables for the corporate sector: 1) the real GDP growth rate in Serbia and in the EU 15 as it is the Serbian main trading partner[15], 2) the Industrial Producer Prices (PPI) growth rate as the indicator of inflation[16], 3) the real industrial production growth rate, 4) the growth rate of the nominal RSD/USD and RSD/EUR exchange rates, 5) the growth rate of the nominal and the real effective exchange rates[17], and 6) the growth rate of the nominal and the real lending interest rates. All rates were obtained on the basis of the quarter to the corresponding quarter of the previous year.

For the household sector model, we use these indicators: 1) the real GDP growth rate in Serbia, 2) the growth rate of the PPI, 3) the growth rate of the unemployment rate[18], 4) the growth rate of the nominal RSD/USD and RSD/EUR exchange rates, 5) the growth rate of the nominal and the real effective exchange rates, and 6) the growth rate of the nominal and the real lending interest rates[19]. Due to the restrictions in the NPLs' time series, the model for both the corporate and the household sectors has been estimated for the period Q3 2004–Q3 2010.

In the case of Serbia, some modifications of the dependent variable were done in order to obtain the sufficiently long time series to run the model. The quarterly values of the NPLs were available for the period from 2008 Q3 to 2010 Q3 (9 observations). In order to extend the time series, we analysed the relationship between the NPLs and the classified assets in categories C+D+E (CDEs), as we assumed the former to be the subcategory of the latter[20]. After

[15]According to the reported data of the NBS's, during the period 1997–2010 the 56.9% of goods were imported from the EU and 54.2% of goods were exported to the EU, on average.

[16]It is more convenient to use the CPI as the measure of the inflation. Due to the lack of data on the CPI for the periods before 2007 we utilise the PPI. Moreover, where practicable, the PPI was used to derive the real values of the other macro indicators.

[17]Annual data on the exchange rates for the years 2003 and 2004 were only available. We multiplied these numbers with the coefficients indicating the relationships between the exchange rates in the available periods and we obtained the estimations for 2003–2004.

[18]For the years 2003 and 2004 the number of unemployed was available only on the annual basis. Therefore, we investigated the change in the number of unemployed during the year on the available data and we applied gained coefficients on the data from the years 2003 and 2004. For the calculation of the unemployment rate the number of unemployed was divided by the number of active population over 15 years, which has been available in the Serbian Statistical Office database (Available at: http://webrzs.stat.gov.rs). The number of active population was available only on the annual basis, hence we assumed it to be constant during the particular year in order to arrive at the unemployment rate.

[19]It is possible to distinguish the lending interest rates for the households and the corporations and to apply the particular rate to the corresponding debtor. Due to the lack of sufficiently long time series on the separate lending rates we do not consider this approach in the case of Serbia.

[20]NBS's definitions of these variables indicate that by subtracting the category C from

the adjustment of the CDEs for the structural break, which was caused by the methodological change in the classifying items and provisions in 2006, and after multiplying the CDEs with the coefficient derived from the observed relationship between the CDEs and the NPLs, we arrived at the estimated NPLs for the period 2004 Q3–2008 Q2. The analysis added another 16 observations to our data set, which now contains 25 observations for the Serbian corporate and household credit risk models.

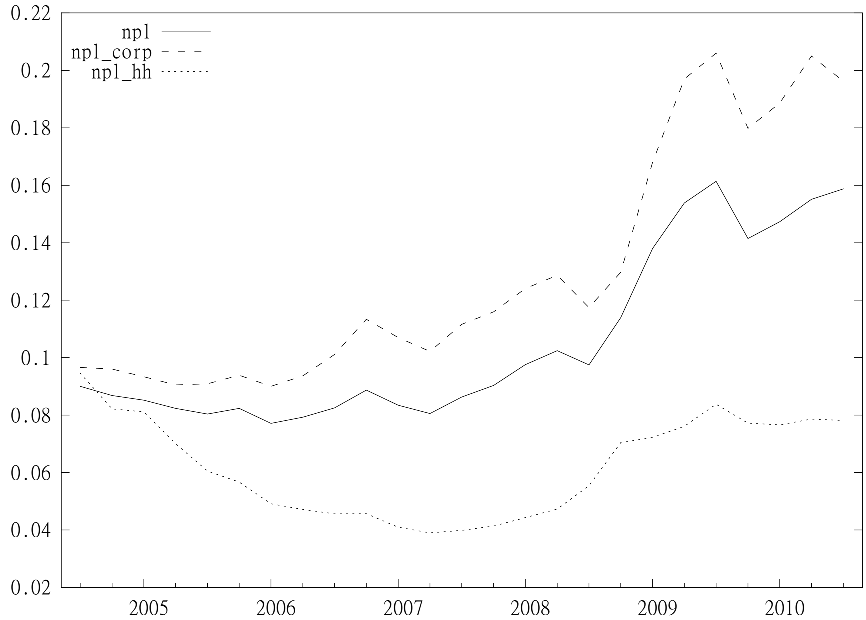
Next, we divided the total quarterly NPLs into the corporate and the household NPLs. The NBS has been reported the sectoral NPLs since the third quarter of 2008. For the previous periods, the division has been done based on the coefficients derived from the relationship between the total NPLs and the sectoral NPLs in the sample period. Finally, we divided the sectoral NPLs by the corresponding total loans, and we obtained the household and the corporate NPL ratios. Figure 4.2 shows the development of the total and the sectoral NPL ratios over time. The NPL ratio, which represents the default rate, remains almost stable during the period from 2004 to mid–2007, demonstrating the slightly increasing tendency for the corporate loans and the little decreasing trend for the household loans. From mid–2007 all indicators increase, especially noticeable is the sharp increase in the corporate default rate from mid–2008 to mid–2009. The corresponding period reflects the appearance of crisis in Serbia.

In the comparable period, the Serbian default rates demonstrate the similar path as those of Croatia. Low values of the default rate at the middle of decade are replaced by the increase after the 2008 turmoil. The Serbian default rates are characterised by higher volatility, as well as higher absolute values than those of Croatia (see Figure 4.2). In the case of Croatia, all rates (total, corporate sector and household sector) show more or less the similar trends, mainly at the end of the period. On the other hand, the Serbian rates differ, particularly the household default rate during the whole sample period. Relatively low default rates for the households compared to those of the corporations in the case of Serbia could be caused by the lower demand for the household lending or the higher requirements for the credit granting. Thus, the debtors might be of higher repayment discipline.[21] However, relative to the household default rates in the other countries, the Serbian ones are elevated. The higher repayment discipline of the households is demonstrated also in Croatia. The share

the CDEs we can arrive at the NPLs values. For the exact definitions of the NPLs and the categories of the classified assets we refer to NBS (2011).

[21] The household loans represent 28.5% of all loans on average, whereas the corporate loans account for 62.5% of the loans in the period 2004–2010.

Figure 4.2: Total NPL ratio and estimated NPL ratios for the corporate and the household sectors in Serbia.



Source: Author's computations. Variables *npl*, *npl_corp* and *npl_hh* represent total NPL ratio, corporate NPL ratio and household NPL ratio, respectively.

of the household loans and the corporate loans to the total loans is almost the same (slightly below 50% for the recent years). Yet, teh households' rates are by 3% lower than those of corporations, on average (the default rates of 8% and 11% for the households and the corporations, respectively).[22]

4.3 Credit Risk Model for the Corporate Sector

In the whole study we use the econometric software Gretl 1.9.1csv. The macroeconomic indicators for Croatia and Serbia were chosen based on the existing literature, the data availability, the availability of data projections and the expert judgement, with the aim to consider the data that would explain the default rates in the meaningful fashion. We consider also the time lags of the variables in order to describe the model realistically. The matrix of the correlation coefficients for each country has been derived to identify the possible correlations between the explanatory variables. We presumed that there could be the correlations primarily between the variables concerning the interest rates

[22]Note that the provided default rates can slightly differ from the actual ones, especially at the beginning of the period. The difference can be caused by the modifications that were carried out in order to obtain longer time series.

and the exchange rates, which have been proved. The significant correlation between the industrial production growth rate and the GDP growth rate in Serbia and between the GDP growth rate in the EU 15 and the growth rates of the industrial production and the nominal and the real effective exchange rates appeared (see Table B.1 in Appendix B). In the case of Croatia we found the correlation between the Croatian GDP growth rate and the EU 15's GDP growth rate, the rate of growth of the unemployment rate, the real interest rate growth rate (total and household lending) and the disposable income growth rate (see Table B.2 and B.3 in Appendix B). We aimed not to include the correlated variables together in the model.[23]

Next, all variables were tested for stationarity. Despite of the relatively short time series the results of the tests suggest that we should not deny the stationarity of the variables.[24] The regression analysis was performed using the Ordinary Least Squares (OLS) method that was applied to the default rate (NPL ratio) expressed in the logistic form.[25] We started with the univariate regression analysis to select the significant explanatory variables and their lags, then we applied the step–wise regression to detect the model that explains the corporate'default rate most properly. Following Jakubík & Schmieder (2008) and being aware of the relatively short sample period that is used we included as few explanatory variables as possible in the final model. Accordingly, we control the model for the possible structural breaks using the QLR test and the additional Chow's and CUSUM tests. The following subsections present the specific credit risk models for Croatia and Serbia.

4.3.1 Croatia

The macroeconomic credit risk model that appeared to explain the default rate movements of the Croatian corporate sector in the best possible way looks as follows:

[23]The correlation coefficient was above 0.5 in the absolute values also for (1) the GDP growth rates in the EU 15 and Serbia, (2) the GDP growth rate and the rate of growth of the unemployment rate and the real interest rate in Croatia, and (3) the growth rates of the unemployment rate and the HRK/USD exchange rate in Croatia. Nevertheless, the small break of the bounds, which were set by the expert judgement in the interval [-0.5,0.5], and the relative importance of the variables encouraged us to use them together in the model. Alternatively, we test all models for collinearity, which was not proved in none of them.

[24]The KPSS test's null hypothesis that the variables are stationary was not denied.

[25]For the control of assumptions of the OLS method, see Table B.4 in Appendix B.

$$
\begin{aligned}
ln\left(\frac{npl_{corp,t}}{1-npl_{corp,t}}\right) &= \alpha + \beta_1 g\_hr_{t-4} + \beta_2 r_{t-4} + \beta_3 \pi_{t-3} \\
&+ \beta_4 er\_usd_{t-2} + \beta_5 dum1_t + \beta_6 dum2_t
\end{aligned}
\tag{4.4}
$$

where $npl_{corp,t}$ is the default rate defined as the portion of the corporate NPLs to the total corporate loans in time t, g_hr denotes the GDP growth rate in Croatia, r is the growth rate of the real interest rate, π is the inflation measured by the CPI, er_usd stands for the growth rate of the HRK/USD exchange rate and $dum1$ and $dum2$ are dummy variables that adjust the model for the structural breaks, which have been detected and proved by QLR and Chow's tests. The value of $dum1$ is 1 for period until the fourth quarter of 2004 and 0 afterwards. Accordingly, the value of $dum2$ is 1 until Q3 2005 and 0 afterwards (see Figure B.1 in Appendix B). The time lags are also indicated. The structural breaks could be caused by the mergers of three big banks with three medium–size banks in 2004.[26]. Next, on January 1, 2004 the new regulations that introduced the new balance–sheet items (i.e. derivative financial assets and liabilities and other financial liabilities held for trading) came into force as a part of the harmonisation process with the EU directives[27], the Basel Committee on Banking Supervision's (BCBS's) and the International Accounting Standards' (IAS') regulations. In 2005, two new banking groups were established as a result of the changes in the ownership structure of the banks operating in Croatia. Also, during 2005, the CNB was constantly growing the allocated reserve and the marginal reserve requirements.[28]

The results from the regression are summarised in Table 4.1.[29] According to our results, the most significant variables that explain the corporate sector default rate in Croatia are the real domestic GDP growth rate, the growth rate of the real interest rate, the inflation and the growth rate of the nominal

[26]Mergers: Privredna banka Zagreb with Riadria banka, Zagrebačka banka with Varaždinska banka, and Nova banka with Dubrovačka banka. Moreover, Croatian National Bank (CNB) did not revoke bank license for Primus banka d.d., which, therefore, started the closing procedure (CNB 2005a).

[27]Stabilisation and Association Agreement with the EU came into force in February 2005.

[28]The marginal reserve requirement rate increased by 16%, the kuna reserve requirement rate by 10% and the portion of foreign currency reserve requirement allocated in kuna by 8% in the first half of 2005 (see CNB 2005b, p. 22).

[29]All values refer to the dependent variable defined in the logistic form which, however, does not change the rule of proportion. In order to derive at the original default rate, we need to calculate Equation 4.4 using the regression coefficients, with respect to $npl_{corp,t}$. The same rule is valid for all regressions in this chapter.

Table 4.1: Corporate sector credit risk model for Croatia.

Variable	Lag	Coeff. value	Std. error	P–value
$constant(\alpha)$	0	-2.4229	0.0516796	2.38e-030
$g\_hr(\beta_1)$	-4	-3.6435	0.688311	9.26e-06
$r(\beta_2)$	-4	0.0779	0.0241417	0.0030
$\pi(\beta_3)$	-3	3.5724	1.04595	0.0018
$er\_usd(\beta_4)$	-2	1.0648	0.155056	1.07e-07
$dum1(\beta_5)$	0	0.2440	0.0504319	3.41e-05
$dum2(\beta_6)$	0	0.3347	0.0515974	3.09e-07
R–squared:	0.944061	Adjusted R–squared:		0.933234
Rho:	0.043723	Durbin–Watson:		1.850616

Source: Author's computations.

exchange rate of Croatian kuna (HRK) against US dollar (USD). All variables are significant at the 1 % significance level. There was a noticeable improvement in the performance of the model when we added dummy variables.[30]

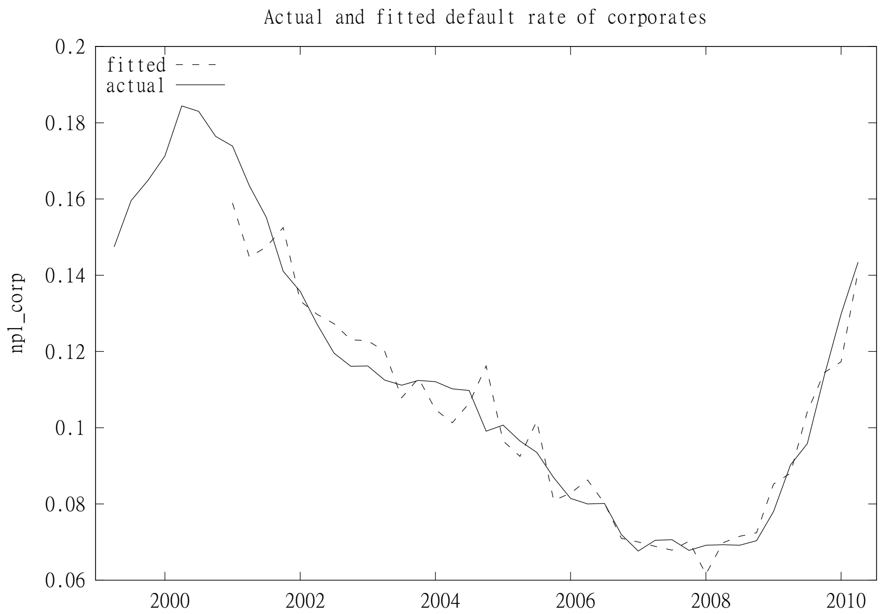
Apart from the real domestic GDP growth rate all coefficients of the explanatory variables have positive signs that indicate that the higher the value of the variable the higher the default rate. Empirically, the increasing GDP affects positively demand for goods that companies' produce, which in turn increases their profits and creditworthiness. Positive impact of the GDP growth on the debt repayment was confirmed by our model. The four–quarter lag indicates a delay in the corporations' response to the changes in the economic conditions, which could be caused by, for example, fixed contracts with their business partners. The positive impact of the increasing interest rate on the default rate is also intuitive, as higher interest rates increase the firms' costs of loans, and that can cause problems in the loans' repayment.

The coefficients for the inflation and the growth rate of the HRK/USD exchange rate have the positive signs. The positive effect of the inflation and the depreciation of domestic currency on the default rate can be in contrast with prevailing expectations. As an explanation we should note that the inflation can induce the default rate to grow if the increasing price level forces companies to spend more money on other commodities because they become more expensive. Thus, the corporations have less resource to repay the debt, even though the debt becomes cheaper. Also, Baboušek & Jančar (2005) in their simulations of the quality of the aggregate loan portfolio in the response to the

[30]The case of all models in this chapter.

macro shocks reject the hypothesis that the inflation helps to improve debtors' creditworthiness. The impact of the depreciation of domestic currency on the default rate depends on the position of exporters and importers in the economy. The positive impact of the depreciation on the default rate can suggest that there are more importers in the economy, for whom the depreciation increases the cost of goods that are imported and thus causes the problems with the debt repayment. In fact, the Croatian trade balance has been negative for the whole period 1999–2009.[31]

Figure 4.3: Actual and estimated corporate sector default rate for Croatia.



Source: Author's computations.

The performance of the estimated model is shown in Figure 4.3.[32] The default rate is measured by the NPL ratio. At the beginning of the period there was the relatively high level of the default rate, exceeding 18% in the mid–2000. However, the default rate was then rapidly falling until 2007, when it reached the level of 7%. The international financial crisis negatively affected

[31]The negative trade balance means that the volume of imports exceeds the volume of exports. Considering the trade with all countries in the world and in all products, the Croatian trade balance in period 1999–2009 was -6 930 million EUR on average (Source: Eurostat database, available at: http://epp.eurostat.ec.europa.eu).

[32]Note that the plotted values in Figure 4.3 are the original default rate values that were derived back from the logistic form used in the regression analysis. The descriptive statistics of the model belongs to the dependent variable in the logistic form. Unless stated otherwise, all figures in this chapter refer to the original default rates, whereas the models' statistics are based on the dependent variable in the logistic form.

Croatia in 2008. The corporate sector has responded by the steep increase in the corporate default rate. In Q2 2010, the default rate was more than 14%. The estimated model follows the actual values relatively well, especially at the end of period, where it demonstrates lower volatility than at the beginning of the period.

Table 4.2: Descriptive statistics of the explanatory variables in the corporate sector credit risk model for Croatia.

Variable	Mean	Std. deviation	Min	Max
g_hr	0.028816	0.03699	-0.069	0.068
r	0.2362	0.90721	-0.76004	4.3877
π	0.028474	0.01606	0.007	0.076
er_usd	-0.039901	0.094945	-0.17118	0.23208

Source: Author's computations.

The descriptive statistics for the explanatory variables is provided in Table 4.2 (time period Q1 2001–Q2 2010). The mean values of the domestic GDP, the real interest rate and the inflation indicate the growing tendency on average, although, apart from the inflation all of them experienced also periods of decrease. The mean value of the exchange rate of HRK against USD points out the appreciation on average. The highest volatility can be found in the growth rate of the interest rates, with the standard deviation of more than 90%.

4.3.2 Serbia

The estimated macroeconomic credit risk model for the Serbian corporate sector is as follows:

$$ln\left(\frac{npl_{corp,t}}{1-npl_{corp,t}}\right) = \alpha + \beta_1 g\_srb_{t-4} + \beta_2 g\_eu_t + \beta_3 er\_eur_{t-1} + \beta_4 dum_t \quad (4.5)$$

where $npl_{corp,t}$ is the default rate defined as the portion of the corporate's non–performing loans to total corporate's loans in time t, g_srb denotes the GDP growth rate in Serbia, g_eu is the GDP growth rate in the EU 15, er_eur stands for the growth rate of the RSD/EUR exchange rate and dum represents the dummy variable, which adjust the model for the structural break that have been detected and proved by QLR and Chow's tests (see Figure B.2 in Appendix B). The dummy has the value 1 for the period until the fourth quarter of 2008 and the value 0 afterwards. The time lags are also indicated. The structural break at the end of 2008 can be caused by the large accounting changes that came into force on July 1, 2008, especially the changes in computing and recording receivables, liabilities and lending activities.[33] Moreover, the year 2008 was in sign of the rapid growth in lending activity that was dominated by the credits to corporations. The corporate lending rose by 45% over the year whereas the household lending increased by 20%. A 20 % increase in the household lending in 2008 is in contrast with the end of 2007 when its increased by 54% relative to the end of 2006.

Table 4.3: Corporate sector credit risk model for Serbia.

Variable	Lag	Coeff. value	Std. error	P–value
$constant(\alpha)$	0	-1.2588	0.0464869	3.11e-017
$g\_srb(\beta_1)$	-4	-1.2061	0.561145	0.0440
$g\_eu(\beta_2)$	0	-6.0872	1.59602	0.0011
$er\_eur(\beta_3)$	-1	-1.0998	0.241101	0.0002
$dum(\beta_4)$	0	-0.6843	0.0587632	2.31e-010
R–squared:	0.95049	Adjusted R–squared:		0.940587
Rho:	0.004727	Durbin–Watson:		1.916890

Source: Author's computations.

Table 4.3 summarises the results from the regression analysis of the Serbian corporate sector. We found that the most significant variables are the real GDP growth of Serbia and the EU 15 and the growth of the nominal exchange rate of Serbian dinar (RSD) against euro (EUR). All coefficients of the explanatory variables have negative signs, the outcome that is in line with the assumptions of the negative impact of GDP growth and currency depreciation on the default rate in the small export–oriented country.

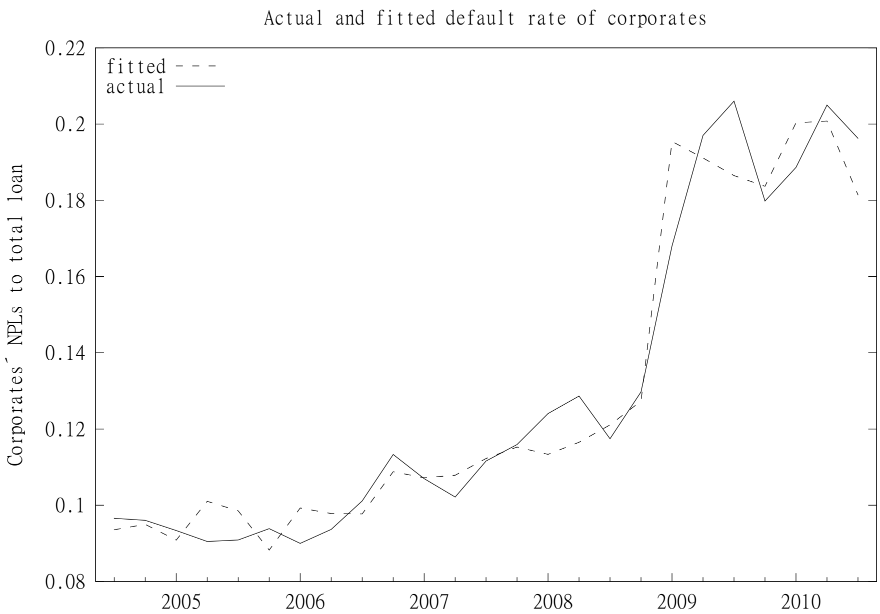
The transmission channels between the GDP growth and the default rate are relatively easy to trail. The increasing GDP stimulates the demand for goods that corporations produce and that increases their profits and ability to repay the debt. The probability of default decreases.A similar view is behind the negative impact of the EU 15's GDP growth since the major part of the

[33] Chart of Accounts and Content of Accounts within the Chart of Accounts for Banks, Guidelines on the Obligation and Methodology of Recording, Compiling, Processing and Delivery of Data on the Stock and Structure of Lending, Receivables and Liabilities of Banks, and Rules on the Forms and Content of Items in Financial Statement Forms to be Completed by Banks (see NBS 2008).

Serbian foreign trade is exported to the EU. The different time lags of the two variables and higher coefficient in the absolute values for the EU's GDP could be caused by higher sensitivity of exporting firms. It is possible that exports consist mainly of goods that react cyclically to the changes in economic conditions (i.e. cars and machinery) and that contracts are fixed on the short periods.[34]

The significance of the Serbia's relations to the EU is further demonstrated by the third variable, the RSD/EUR exchange rate that was more significant than exchange rate of dinar against USD, for example. The negative impact of depreciation of the domestic currency on the default rate is given by the fact that the currency depreciation favours domestic exporters and increases their profits, which in turn helps to decrease their default rates.

Figure 4.4: Actual and estimated corporate sector default rate for Serbia.



Source: Author's computations.

The performance of the estimated model is demonstrated in Figure 4.4. In the first years of the period there was a relatively low level of the default rate (below 10%) compared to the following period that was characterised by the steep increase of the default rate in mid–2008 with the two peaks in mid–2009 and 2010.[35] The end of the period indicates the default rates to be around

[34]In fact, the machinery, the apparatus and the transport equipment form the third biggest group of the Serbian exports in the last three years, according to the NBS's reports.

[35]In comparison to the other countries, this value is still very high. Jakubík & Schmieder

20%. The values reflect the relatively high portion of the "bad" loans and can indicate persistent problems in the banking sector in Serbia. The estimated model captures the pattern of the actual values more or less properly.

Table 4.4: Descriptive statistics of the explanatory variables in the corporate sector credit risk model for Serbia.

Variable	Mean	Std. deviation	Min	Max
g_srb	0.044196	0.041625	-0.044797	0.13677
g_eu	0.012993	0.013750	-0.013204	0.029750
er_eur	0.067411	0.084821	-0.0811	0.21429

Source: Author's computations.

Descriptive statistics for the explanatory variables in the Serbian credit risk model is provided in Table 4.4 (time period from Q1 2004 to Q3 2010). The mean values of the Serbian and the European GDPs and the exchange rate of dinar against euro show their growing tendency on average, although all of them experienced also periods of decrease. The growth rate of the exchange rate experiences the highest volatility with the standard deviation of almost 8.5%.

When we compare the estimated models for Croatia and Serbia we can see some similarities, especially the significance of domestic GDP growth rate and growth rate of exchange rate for both countries. Both Croatia and Serbia have the managed floating exchange rate regimes. The dependence of the default rate on the exchange rates points to the small open economies that rely heavily on the international trade. Serbia seems to be more dependent on the trade with the EU as GDP of the EU and the exchange rate of dinar against euro are remaining explanatory variables beside the domestic GDP growth. Croatian corporate sector default rate reacts more on the exchange rate of kuna against the leading currency in the international trade–the US dollar. Remaining explanatory variables are rather domestic– the GDP growth, the price level and the interest rate. Probably due to the shorter sample period in the case of Serbia, the estimated Croatian model fits better the real values and does not experience such volatility as the Serbian one.

In the credit risk model of the Croatian and the Serbian corporate sectors the macroeconomic factors other than those described above appeared to be

(2008) analysed the corporate sector default rates in the Czech Republic and Germany and their values in 2006 were around 3% and 1.5%, respectively.

non–significant or not appropriate in an economic sense, especially in the combination with other factors. We controlled the appropriateness of the model using all tests required for the OLS method, namely the normality of residuals, the homoscedasticity, the autocorrelation of residuals and the collinearity of variables. Moreover, we tested the stability of parameters using the CUSUM test and the adequateness of the model specification using Ramsey's RESET test. None of tests revealed any distresses. The models' coefficients of determination are very high, demonstrating the good performance of the models when explaining the evolution of the default rates. However, given the relatively small sample period especially in the case of Serbia, R–squared or adjusted R–squared could be lower if we add more observations. More observations could even change the output or bring more significant variables. What is more, the estimated Serbian NPLs from the CDEs for the sample period until mid–2007 and the various NBS's and CNB's methodological changes during the observed period indicate that we should be conservative when interpreting the model. Thus, we do not see the models as benchmarks that have to be valid in every situation. For our purposes and with available data, however, the models demonstrate the relatively good performance and the predictive power.

4.4 Credit Risk Model for the Household Sector

Similarly to the credit risk model for the corporate sector we verified the basic assumptions as stationarity and correlation between variables before initiating regression analysis for the household sector model. The regression was again performed using the OLS method, applied to the default rate (NPL ratio for the household sector) in logistic form.[36] Firstly, we ran the univariate regression analysis to detect the significant variables and their lags. In the step–wise regression the variables interacted and we modified them in order to obtain meaningful model that fits data in the best possible way. Using the QLR test we controlled the model for the structural breaks. If a structural break was found, the dummy variable was added to adjust the model for the structural break.

[36] For the control of assumptions of OLS method, see Table B.5 in Appendix B.

4.4.1 Croatia

The estimated macroeconomic credit risk model for the household sector in Croatia is as follows:

$$
\begin{aligned}
ln\left(\frac{npl_{hh,t}}{1-npl_{hh,t}}\right) &= \alpha + \beta_1 g\_hr_{t-2} + \beta_2 u_{t-3} + \beta_3 \pi_{t-5} \\
&\quad + \beta_4 dum1_t + \beta_5 dum2_t
\end{aligned}
\tag{4.6}
$$

where $npl_{hh,t}$ is the default rate defined as the portion of households' non–performing loans to total households' loans in time t, g_hr denotes the GDP growth rate in Croatia, u is the growth rate of the unemployment rate, π stands for the inflation measured by the CPI and $dum1$ and $dum2$ are dummy variables that adjust the model for the structural breaks, which have been detected and proved by QLR and Chow's tests. The value of $dum1$ is 1 for periods prior to Q3 2004 and 0 afterwards. The value of $dum2$ is 1 until Q4 2006 and 0 afterwards (see Figure B.1 in Appendix B). The time lag of every variable is indicated. The first structural break represented in the model by $dum1$ has probably the same grounds as the first structural break in the Croatian corporate sector model. The second structural break is not easy to interpret. It could be the response to the announced privatisation of the key state–owned steel, shipbuilding, telecommunication and oil industries, that should have included the employee ownership (ESOP–Employee Stock Ownership Plan) as the important part of the new ownership structure. The new Privatisation Law, however, never came into force, and what is more, the cancellation of the old one was announced in 2009.[37] Another reason for the structural break could be the takeover of the two banks in Croatia by the foreign banks in 2006 and also the introduction of the new risk weights (the new 75 % risk weight) that led to the change in the structure of credit–risk weighted assets.[38]

Table 4.5 shows the regression results with the macro factors that explain the development of the default rate for the Croatian households. The domestic GDP growth rate has a negative sign, whereas the growth rates of the unemployment rate and the inflation have positive signs. The negative effect of the GDP growth on the default rate results from the fact that similarly to the corporations also the households benefit from the favourable economic

[37] BMI (2006), and Tportal.hr (2009).
[38] CNB (2007).

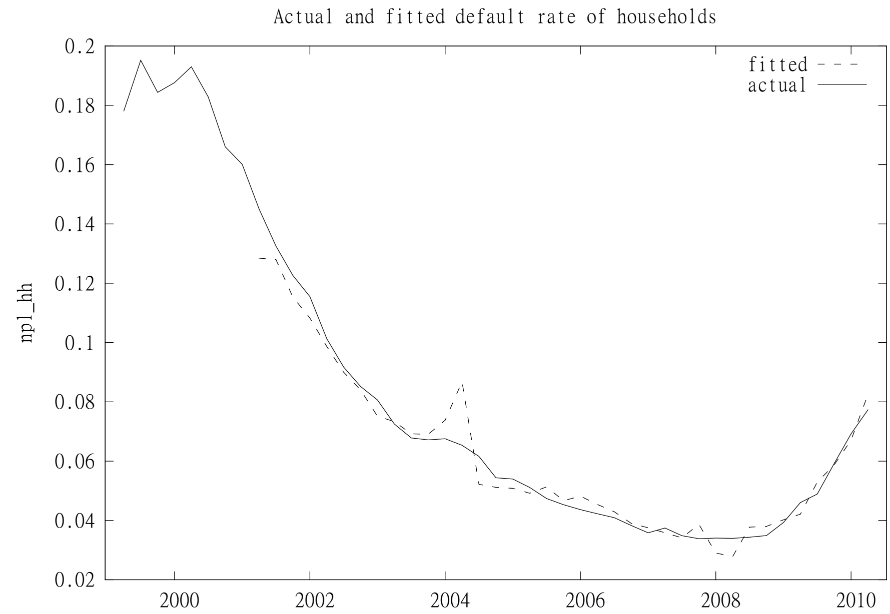
Table 4.5: Household sector credit risk model for Croatia.

Variable	Lag	Coeff. value	Std. error	P–value
$constant(\alpha)$	0	-3.0912	0.0661304	2.60e-030
$g\_hr(\beta_1)$	-2	-1.8276	0.757563	0.022
$u(\beta_2)$	-3	1.7730	0.208148	1.27e-09
$\pi(\beta_3)$	-5	3.2625	1.39434	0.0259
$dum1(\beta_4)$	0	0.5417	0.0488127	2.51e-012
$dum2(\beta_5)$	0	0.2026	0.0533838	0.0006
R–squared:	0.954021	Adjusted R–squared:		0.946605
Rho:	0.041182	Durbin–Watson:		1.846594

Source: Author's computations.

conditions. Conversely, the increasing unemployment causes the default rate to grow as more people lose jobs and their creditworthiness decreases. The inflation again, as in the case of Croatian companies, increases the default rate probably because people spend more resources on the other commodities. The relatively long lags in the case of the inflation and the unemployment suggest that it takes some time until households react to the changes in these variables and that they possibly hold some reserves they can use in the case of distress.

Figure 4.5: Actual and estimated household sector default rate for Croatia.



Source: Author's computations.

Figure 4.5 demonstrates the Croatian household sector default rate for the period from Q1 1999 to Q2 2010. In the first two years of the period the default rate reached the values of almost 20%, which were even higher than in the case of the corporate sector. However, from 2001 the default rate was constantly decreasing. In 2007 it rested on approximately 4% rate for another two years. Similarly to the default rate of firms it started to grow in the light of the financial crisis in 2009 and it followed the increasing path until the end of the sample period (see Figure 4.5 and Figure 4.3 in Section 4.3.1for comparison). In Q2 2010 the default rate was around 7.7%. The estimated model catches up the actual values properly, apart from the periods of higher volatility around the years 2004 and 2008.

Table 4.6: Descriptive statistics of the explanatory variables in the household sector credit risk model for Croatia.

Variable	Mean	Std. deviation	Min	Max
g_hr	0.028816	0.03699	-0.069	0.068
u	-0.0315958	0.12523	-0.25688	0.39535
π	0.028474	0.01606	0.007	0.076

Source: Author's computations.

Table 4.6 provides the descriptive statistics of the explanatory variables in the household sector credit risk model (time period from Q1 2001 to Q2 2010). The domestic GDP and the inflation are the same as in the model of corporate sector and for their discussion we refer to Section 4.3.1. The mean of the growth rate of the unemployment rate suggests the decreasing path over the period on average with, however, relatively high standard deviation of 12%.

4.4.2 Serbia

The final macroeconomic credit risk model for the household sector in Serbia is as follows:

$$ln\left(\frac{npl_{hh,t}}{1-npl_{hh,t}}\right) = \alpha + \beta_1 er\_eur_t + \beta_2 u_t + \beta_3 i_{t-3} + \beta_4 \pi_{t-4} + \beta_5 dum_t \quad (4.7)$$

where $npl_{hh,t}$ is the default rate defined as the portion of households' non–performing loans to total households' loans in time t, er_eur is the RSD/EUR exchange rate growth, u is the growth of the unemployment rate, i is the nominal interest rate growth, π stands for the inflation and dum denotes the dummy variable that adjusts model for the structural break that we found to be in place in mid–2008 (see Figure B.2 in Appendix B), with value of 1 for the period prior to Q3 2008 and with the value of 0 afterwards.[39] The origins of the structural break in mid–2008 more likely rise from the same reasons as in the case of the corporate sector model (see Section 4.3). Respective time lags are presented in the equation.

Table 4.7 sums up the regression results and shows the most significant macro factors that explain the development of the default rate for the households. The exchange rate of the Serbian dinar against euro, the growth of the unemployment rate and the nominal lending interest rate growth have positive signs, which indicates that they have the positive impact on the default rate. The negative sign of the inflation suggests the negative impact of this variable on the default rate.[40] All coefficients are significant at 1% level, including the dummy variable. There was a noticeable improvement in the performance of the model when we added dummy variable.

Table 4.7: Household sector credit risk model for Serbia.

Variable	Lag	Coeff. value	Std. error	P–value
$const(\alpha)$	0	-2.1873	0.0870917	1.83e-015
$er\_eur(\beta_1)$	0	1.1616	0.267025	0.0004
$u(\beta_2)$	0	1.6337	0.218626	6.38e-07
$i(\beta_3)$	-3	0.5167	0.110369	0.0002
$\pi(\beta_4)$	-4	-5.1918	0.740572	1.52e-06
$dum(\beta_5)$	0	-0.1806	0.0365485	0.0001

R–squared:	0.959439	Adjusted R–squared:	0.948172
Rho:	-0.003088	Durbin–Watson:	1.904530

Source: Author's computations.

Positive impact of the RSD/EUR exchange rate growth on the default rate[41] might be the result of the preference for loans denominated in the foreign cur-

[39]Chow's test confirmed the presence of the structural break at the end of 2008, when the null hypothesis of no structural break was rejected at 1% confidence level. The CUSUM test demonstrated higher parameters' stability in the presence of dummy variable. Additional Chow's tests did not show any other structural breaks.

[40]The positive impact on default rate means that the growth of variable causes default rate to increase. The negative impact appears when the growth of variable leads to the decrease in the default rate.

[41]That in fact signifies the depreciation of dinar against euro relative to the corresponding period a year earlier.

rency (mostly in euro) for a part of the Serbian households.[42] Non–hedged loans are vulnerable to the foreign exchange rate risk, when the depreciation of domestic currency makes loans to be more expensive and their repayment more difficult to accomplish. The consequences of the growing unemployment or the nominal lending interest rates for the household default rate are intuitive. The rising unemployment brings about more people unable to meet their obligations. No time lag between the increase in the unemployment rate and its effect on the default rate can suggest that the households do not possess any savings on their disposal, or at least, are not willing to use them for the debt repayment if people lose the jobs. The increasing interest rates cause the mark–up of both existing and future loans.[43]

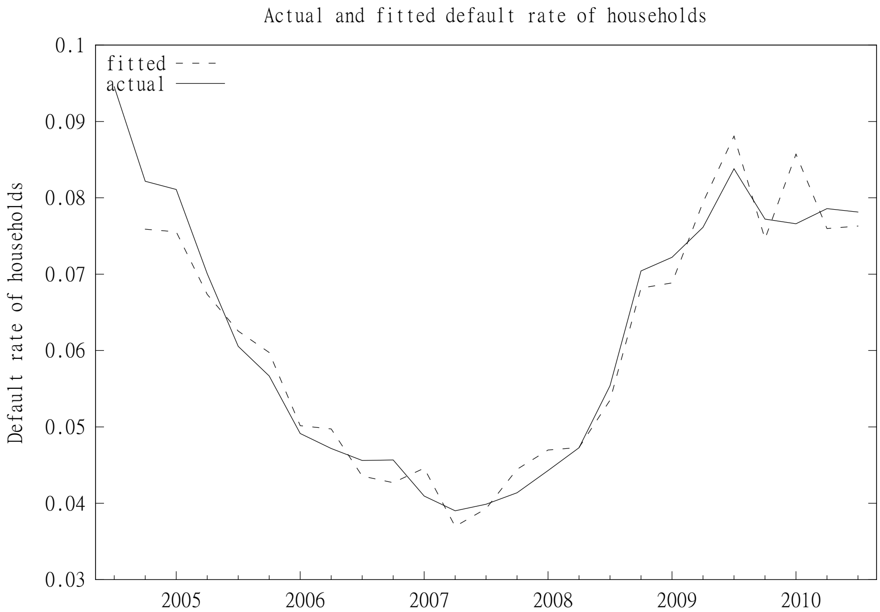
The negative effect of the inflation on the default rate is demonstrated in the deterioration of the real value of debt. Nevertheless, the time lag in turning the effect up more likely signals the prevalence of the negative effect of inflation on households in form of the decreased purchasing power if we assume the rigid wages. The households preserve less resource for their credit obligations. When wages adjust to the new price level, the purchasing power turns to be at the same level and the positive effect of the inflation from the debtor's point of view prevails. To sum it up, all signs are in line with our intuitive expectations about the direction of impact of the individual explanatory variables.

Other variables such as the real GDP growth rate in Serbia, the nominal RSD/USD exchange rate growth, the nominal and the real effective exchange rate growth, and the real lending interest rate growth came up to be insignificant in the model described above. However, they might become significant if the variables and their lags are chosen differently or if the sample period is longer. Yet, given the available dataset of both dependent and explanatory variables, the model described in Table 4.7 shows the best possible performance in estimating the household sector default rate, with satisfactory results of all tests required for the OLS estimates, and moreover with the good explanatory power that is measured by the coefficients of determinacy. Actual and estimated values of the default rate are plotted in Figure 4.6. The high levels of the default rate of almost 10% in 2004 and 2005 were replaced by the sharp decrease until 2007, where the default rate reached its minimum of approximately 4%. In the next period the economic situation deteriorated. The

[42]In the period 2003–2009 the ratio of loans to households denominated in the foreign currency to all household's loans was 3.57%, on average.

[43]Assuming that the interest rates on the loans are not fixed until maturity.

Figure 4.6: Actual and estimated household sector default rate for Serbia.



Source: Author's computations.

following years were in sign of the economic recession, with the peak in the household default rate in 2009 that was, however, not higher than the rates six years earlier. The end of the sample period shows the default rate reaching almost 8%. The estimated model captures this pattern properly, with the exception in the end of 2009, where it shows the different trend. After all, it turns to follow the actual pattern at the end of the sample period, so that we consider its volatility continuously decreases.

Table 4.8: Descriptive statistics of the explanatory variables in the household sector credit risk model for Serbia.

Variable	Mean	Std. deviation	Min	Max
er_eur	0.067411	0.084821	-0.0811	0.21429
u	-0.018288	0.074369	-0.14650	0.093201
i	-0.014288	0.25398	-0.35213	0.62713
π	0.10448	0.036014	0.0490	0.1620

Source: Author's computations.

The descriptive statistics of the explanatory variables for the period from Q1 2004 to Q3 2010 is available in Table 4.8. The variable that is volatile the most turns out to be the nominal interest rate with the standard deviation of

25%. Although all variables show positive as well as negative growth rates, the inflation reaches only positive values which indicate that there were no deflationary periods in the sample. The mean values suggest the unemployment rate and the nominal interest rate to decrease and the inflation and the exchange rate of dinar against euro to increase, on average.

Estimated models for the households both in Croatia and Serbia identify the growth rate of the unemployment rate and the inflation as the significant variables in explaining the default rates' movements. In both countries the unemployment increases household's probability of default as the working is traditionally the main source of income. The inflation influences countries' default rates in opposite ways, having the negative effect on the default rate in the Serbian model and the positive effect in the Croatian one. It seems that Serbian households respond to the increase in inflation that causes debt to be cheaper by improving repayment discipline, even though if it goes in line with the higher prices of other commodities. On the other hand, the case of Croatia suggests that if the price level increases, the households shift their resources from repaying the debt to purchasing commodities that become more expensive, thus the default rate increases. Nevertheless, both countries react on the inflation with the relatively long delay. In the remaining explanatory variables the two countries differ.

Similarly as in the corporate credit risk models, the model of Croatia shows better performance and lower volatility probably due to more observations used. Again, we controlled if all assumptions of the OLS model were fulfilled. All test for the normality of residuals, the homoscedasticity, the autocorrelation of residuals, the collinearity of variables showed no deviation from the preliminary assumptions. Moreover, the CUSUM test for the stability of parameters and Ramsey's RESET test for the adequateness of the model were performed. Both models demonstrate the relatively good performance and the predictive power. Yet, as in the corporate sector model we should be aware of the relatively short sample period and we should not regard the models as benchmarks. As a part of the future research it could be appropriate to revise them on the longer time horizon.

Chapter 5

Macro Stress Testing

5.1 Scenario Analysis

This section develops two scenarios that project the macroeconomic conditions for Croatia and Serbia that will be used in the stress testing on the individual bank's level. The baseline scenario reflects the most likely evolution of the macroeconomic factors in the one year horizon starting from the end of 2010 and ending in the fourth quarter of 2011. For the stress testing of the individual banks the macro conditions in Q4 2011 are relevant. The baseline scenario is formulated in line with the forecasts provided by the international organisations, such as the International Monetary Fund (IMF), or the macroeconomic survey companies as the Consensus Economics (Consensus Forecasts) and the Business Monitor International (BMI).[1] If not available elsewhere, we use the forecasts of domestic governmental organisations, usually to support or adjust the forecasts from other sources.[2] In the one year horizon some variables even need not to be projected due to the time lags in the macro credit risk models.

The adverse scenario is set by the expert judgement, using the observed values of the individual variables in the past. Our shock consists of the movements in all variables that enter the credit risk model, contrary to some studies that stimulate only one variable per shock.[3] We attempt to determine the shock consistently, that is to utilise the maximum movements of the variables from the overlapping periods. This method is so–called historical simulation stress

[1] Analogous approach was applied in the Federal Reserve System's (Fed's) implementation of the Supervisory Capital Assessment Program (SCAP), see Board of the Governors of the Federal Reserve System (2009a).

[2] In case the forecasts are not available, another possibility is to employ simple vector autoregressive model (VAR).

[3] The approach was used i.e. in Jakubík & Schmieder (2008).

testing. The adverse scenario is plausible because the considered values have been already observed. That brings our hypothetical adverse scenario closer to reality, maybe at the expense of the severity of the shock.[4] The scenarios consider two sources of risk: the credit risk and the market risk (divided into the interest rate and the exchange rate risks). For each sector the baseline and the adverse scenarios are the same.

5.1.1 Croatia

In this section we develop the one year horizon baseline and adverse scenarios for Croatia. For the variables that enter the credit risk model developed in Chapter 4 we present the projected values according to the scenario. For the baseline scenario that should reflect the most likely situation at the end of 2011 we employ projections from the BMI Emerging Europe Monitor[5], Consensus Forecasts[6] and actual values from the CNB's database.[7]

More specifically, the baseline situation might look as follows (Table 5.1): at the end of 2010 Croatia experiences the negative GDP growth, which affects the default rate of the corporations at the end of 2011. During 2011 we expect the positive GDP growth that affects positively the creditworthiness of the Croatian households at the end of the year. There is a 12 % drop in the real interest rate in Q4 2010 relative to the same period a year ago. The drop favours corporate debt repayment. Relatively low inflation of 1.4% in 2010 has increased to 3.4% in 2011. According to the credit risk model estimated for the corporate sector in Chapter 4 the higher inflation increases the corporate default rate. We expect Croatian kuna to appreciate against US dollar by 10.6% in Q2 2011 relative to the corresponding period a year ago that was in the sign of depreciation. The appreciation affects negatively the corporate default rate. The unemployment rate continues to rise. The described macro variables enter the credit risk models of the corporate and household sectors.

[4] On the contrary, we could line up the observations and take those ones that belong to the 5–10% bottom quantile. Boss (2002) utilises the historically observed maximum movements of the macro variables in the scenario. In this case, however, the scenario needs not to be consistent because the variables can demonstrate maximum movements in the quite different periods. Oppositely, Virolainen (2004) sets shock expertly by increasing or decreasing the values of the variables by certain percentage points.

[5] See BMI (2011).

[6] Consensus Economics (2010a,b)

[7] Namely, we used data from the Consensus Forecast to project the GDP growth rate and the inflation and the BMI data for the HRK/USD exchange rate. The unemployment rate was adopted from the Eurostat database and the real interest rate from the CNB. Some values were not projected due to their time lag in the model.

The results of the models are the estimated probabilities of default (default rates) that will be further used in the computations of the credit risk losses on the individual bank's level.

Table 5.1: Explanatory variables that enter the credit risk models for the actual, the baseline and the adverse scenarios in Croatia.

Corporate sector	Time lag	Actual (%)	Baseline (%)	Adverse (%)
g_hr	-4	-6.9	-0.6	-6.7
r	-4	439	-12	18
π	-3	1.0	3.4	6.4
er_usd	-2	13.3	-10.6	- 4.0
Household sector	**Time lag**	**Actual (%)**	**Baseline (%)**	**Adverse (%)**
g_hr	-2	-0.05	0.02	-5.7
u	-3	26.8	23.9	36.3
π	-5	3.8	1.4	1.4

Source: Author's computations. The actual scenario refers to Q2 2010, the baseline and the adverse scenarios to Q4 2011. Variables *g_hr*, *er_usd*, u, r and π represent the growth rates of the Croatian GDP, the HRK/USD exchange rate, the unemployment rate, the real interest rate, and the inflation, respectively. The values are showed with respect to time lag in which they appear in the model (for example, Croatian GDP growth rate of -6.9% is the value of Q2 2009 that due to time lag appears in the model that estimates Q2 2010 situation).

The economic conditions regarding the market risk at the end of 2011 are described in Table 5.2. For the calculation of the bank's interest rate losses the CNB's key interest rate is relevant. The CNB has not changed it since 2008 and it was announced that the rate would not change in the first half of 2011. We assume that the rate will rest on 9% until the end of 2011 for the baseline scenario. For the exchange rate losses we use the projected exchange rates of kuna against the US dollar and the euro from the BMI's forecasts. These are 7.01 and 5.27 HRK/EUR and HRK/USD, respectively.[8] The rates reflect the appreciation of kuna. The comparison to the situation in Q4 2010 is provided in the table. The overall baseline scenario suggests that in 2011 Croatia might experience the economic recovery.

In the adverse scenario we have changed all variables except for the inflation in the case of the households, due to its time lag. Especially, the growth rates of GDP and the real interest rate demonstrate highly different paths relative

[8]Note that conversely to the credit risk, in the case of the market risk there are no time lags.

Table 5.2: Variables that enter the market risk's computation for the actual, the baseline and the adverse scenarios in Croatia.

	Actual	Baseline	Adverse
i_cnb	9%	9%	11%
Change to actual scenario	–	+0%	+2%
er_eur	7.39	7.01	7.29
Change to actual scenario	–	-0.38	-0.10
er_usd	5.57	5.27	5.00
Change to actual scenario	–	-0.30	-0.57

Source: Author's computations. The actual scenario refers to Q4 2010, the baseline and the adverse scenarios to Q4 2011. Variables *i_cnb*, *er_eur* and *er_usd* indicate the CNB's key interest rate, the HRK/EUR and the HRK/USD exchange rates. The values of the baseline and the adverse scenarios will serve as inputs in the computations of individual bank's losses from the market risk.

to the baseline scenario. The adverse scenario reflects the prolongation of the crisis from 2008 or, more specifically, its return after the relatively good conditions in 2010. The influence of 2010 values in the 2011 estimations via the credit risk models causes that the effect of the shock on the default rates is noticeable only in the end of 2011. The default rates in the adverse scenario show the same trend as in the baseline scenario, except for the end–of–year values. Yet, in the two–year horizon the effect of the shock could be fully translated into the deterioration of the default rates. Specifically, we assume the negative domestic GDP growth rate of more than 5% through the whole year, the situation experienced in 2009. We let the inflation and the unemployment rate to increase, the situation that was observable in some periods of the recent crisis in Croatia. We suppose also that the CNB perceived increasing inflation and that it aims to fight it by elevating its interest rate. The result is the increase of banks' interest rates. The intervention does not lower the inflation until the end of the year, which in our credit risk model would be noticeable in 2012.

For the market risk calculation the input variables in the adverse scenario are chosen as follows: Assuming the CNB's efforts to lower inflation, we increase its base interest rate for 2%. The increase will negatively affect banks' available–for–sale securities in the balance sheets. It will affect also the interest income that arises from the maturity gap between interest sensitive assets and liabilities, however with the uncertain impact. For the exchange rate risk we assume the two main exchange rates, kuna against euro and kuna against US dollar. They are set according to the 2009 values. For the both cases the kuna appreciates relative to the Q4 2010 values. The impact of the exchange rates on the banks' portfolio will depend on the net open foreign exchange (FX) position of the bank in the particular currency. The credit risk default rates arisen from the scenarios are depicted in Figures 5.1 and 5.2 in Section 5.2.1.

5.1.2 Serbia

This section describes the set up of the 2011 scenarios for Serbia. For the on year baseline estimations of the Serbian and the EU 15's GDP growth rates and the growth rates of the unemployment rate and the RSD/EUR exchange rate we employed the projected data from the Consensus Forecasts, the IMF World Economic Outlook[9], the BMI Emerging Europe Monitor and the Centre for Strategic Economic Studies "Vojvodina–CESS".[10] Due to time lags of the inflation and the growth rate of the nominal interest rate in the credit risk models we did not forecast these variables.

Table 5.3: Explanatory variables that enter the credit risk models for the actual, the baseline and the adverse scenarios in Serbia.

Corporate sector	Time lag	Actual (%)	Baseline (%)	Adverse (%)
g_srb	-4	-2.19	3.30	-4.29
g_eu	0	2.40	1.40	-0.87
er_eur	-1	11.70	-1.01	- 6.04
Household sector	**Time lag**	**Actual (%)**	**Baseline (%)**	**Adverse (%)**
er_eur	0	14.15	-0.38	-1.07
u	0	-0.92	-4.32	4.50
i	-3	-34.95	23.27	60.83
π	-4	5.30	16.20	16.20

Source: Author's computations. The actual scenario refers to Q3 2010, the baseline and the adverse scenarios to Q4 2011. The variables g_srb, g_eu, er_eur, u, i and π represent the growth rates of the Serbian and the EU 15's GDPs, the RSD/EUR exchange rate, the unemployment rate, the nominal interest rate, and the inflation, respectively. The values are showed with respect to time lag in which they appear in the model (for example, the Serbian GDP growth rate of -2.19% is the value of Q3 2009, which due to time lag appear in the model that estimates Q3 2010 situation).

[9] Available at: http://www.imf.org.

[10] Specifically, Consensus Forecasts were used for GDP growth rates projections, BMI's data for RSD/EUR exchange rate, and the average of the IMF's and Vojvodina–CESS & IHS (2011) data on the unemployment rate.

The baseline scenario for the end of 2011 is as follows: at the end of 2011 we expect the EU GDP to grow almost 1.4% relative to the same period a year before. That favours Serbian exporters. The corporations in Serbia also benefit from the expected 3.3 % growth of the domestic GDP at the end of 2010.[11] On the other hand, the expected slight appreciation of dinar causes that the exported goods are more expensive and can reduce the companies' profits. Thus, the overall impact on the corporate default rate depends on its sensitivity to the changes of the given variables. For the households, the appreciation can help to reduce the default rate, as part of the households takes loans denominated in euro. Furthermore, the noticeable drop in the unemployment rate (by 4.32%) and a 16 % increase in the price level at the end of 2010 favour the households.[12]

The NBS has announced the increase of its key interest rate to 12.5% in order to fight accelerating inflation. This intervention puts the NBS in the group of central banks with the highest interest rates. Accordingly, the lending interest rate started to grow at the end of 2010, with 23 % higher values in Q1 2011 compared to the same period last year. As a result the loans will be more expensive and their repayment might be complicated (see Table 5.3 and 5.4). Contrary to the dinar appreciation against the euro, we expect the dinar to depreciate against the US dollar, the projection provided by the forecasters from the BMI at the end of 2010. The impact of the exchange rate changes on banks' portfolios will depend on their net open positions in given currencies.

The adverse scenario assumes the different path of the macro variables that is in the case of the GDPs, the unemployment rate and the nominal interest rate markedly different from the actual situation. In the adverse scenario we suppose the GDP growth of the EU 15 to run the course of the financial crisis (end–2008 value). Also the GDP growth in Serbia experiences the crisis situation from the beginning of 2009. Both regions demonstrate the negative GDP growth, which is in the case of Serbia relatively high, with the value of -4.29%, compared to that of the EU 15 (-0.87%). We suppose the raise in the unemployment, with the unemployment rate growth rate of 4.5% (Q2 2009 value). The efforts of the NBS to fight inflation and higher uncertainty during the shock are reflected in the sharp increase in the lending interest rate (2008 values). The banks are not willing to provide credits and they require high compensation rate for them.

[11] The forecast value of the GDP growth for 2011 was placed in the last quarter of 2010 because the actual values of Q4 2010 has not been available.

[12] Note that the inflation makes loans cheaper from the debtor's point of view.

Table 5.4: Variables that enter the market risk's computation for the actual, the baseline and the adverse scenarios in Serbia.

	Actual	Baseline	Adverse
i_nbs	11.5%	12.5%	13.5%
Change to actual scenario	–	+1%	+2%
er_eur	105.5	105.1	104.4
Change to actual scenario	–	-0.4	-1.1
er_usd	79.3	82.4	85.5
Change to actual scenario	–	-3.1	-6.2

Source: Author's computations. The actual scenario refers to Q4 2010, the baseline and the adverse scenarios to Q4 2011. The variables *i_nbs*, *er_eur* and *er_usd* indicate the NBS's key interest rate, the RSD/EUR and the RSD/USD exchange rates. The values of the baseline and the adverse scenarios will serve as inputs in the computations of individual bank's losses from the market risk.

Around 6 % and 1 % appreciations of dinar against the euro (2010 values) favour the households whose loans are denominated in euro, but negatively affect the exporting companies. The inflation remains the same as in the baseline scenario due to the time lag. Concerning the market risk, we assume the NBS to raise its key interest rate by 1% more than in the baseline scenario. The exchange rates of dinar against euro and US dollar follow the same direction as in the baseline case, but the changes are larger (see Table 5.4). In the following section we will use the results of teh scenario analysis to calculate the market and the credit risks for Croatia and Serbia.

5.2 Credit Risk

In Chapter 3 we discussed the risks to which the bank can be exposed. The credit risk is the main risk that banks face due to their role of the intermediary between the agents with the surplus and those with the shortage of resources. Granting loans is the unfinished transaction until the debt is fully repaid (Mejstřík, Pečená, & Teplý 2008, p. 253). There always exists the threat that the debtor will not meet its obligations and that the loan or its part will not be repaid, which will cause the loss in the bank's accounting books. Revealing its key role in banks' exposures, authors that deal with the banking sector stress testing usually model this type of risk (see Boss 2002, Virolainen 2004 or Jakubík & Schmieder 2008).

As discussed in Chapter 3, there are few approaches how to set the macro credit risk model. Chapter 4 introduced the models for the Croatian and the Serbian corporate and household sectors that were developed according to approach originated by Wilson (1997a,b). The models estimated the sectors' default rates according to the movements of the specific macroeconomic factors. In this section, we will apply the baseline and the adverse scenarios from Section 5.1 to the models developed in Chapter 4. The results will be the Croatian and the Serbian corporate and household sectors' default rates estimated for the Q4 2011. The default rates will be used as the probabilities of default for the calculation of the credit risk losses in the individual bank's loan books.[13]. The expected and the unexpected credit risk losses are usually calculated according to Basel II principles (see BCBS 2006). In our study we will assume only the expected losses, the method used in i.e. in Jakubík & Sutton (2011). The expected credit risk losses can be calculated as follows:

$$credit\ loss_{t+1} = PD_{t+1} \times LGD_t \times EAD_t \tag{5.1}$$

where PD denotes the probability of default expressed in terms of the default rate, LGD stands for the loss given default and EAD is the exposure at default in time t. Jakubík & Sutton (2011) suggest to measure EAD as the difference between the outstanding loans and the NPLs in time t. The loss given default will be set on the level proposed in Basel II under the foundation approach for the senior claims on corporates, sovereigns and banks with no recognised collateral (45%, BCBS 2006, p. 67) for Croatia. In the case of Serbia we will raise this level to 55%, reflecting the higher uncertainty in the Serbian economic conditions.[14]

[13]For the sake of simplicity we assume the individual banks' portfolio to be homogeneous. Accordingly, we can apply the default rates estimated on the banking sector's level on the individual banks. Note that we have developed two different models for the country's corporate and household sectors that provide the two different default rates. We will divide the bank's portfolio into the loans to corporations and the loans to consumers in order to distinct the loans with different probabilities of default. In the calculation of the credit risk loss of the individual bank the losses from the corporate and household loans will be added together.

[14]As of March 2011, Standard & Poor's provide Croatia and Serbia with ratings BBB+ and BB, respectively (ratings available at http:/www.standardnadpoors.com). The rating of Croatia suggests that the economy has the adequate capacity to meet the financial obligations but also that the economy is the subject to adverse economic conditions, whereas Serbian BB rating suggests that the economy is less vulnerable to the shocks in the near–term but it faces ongoing uncertainties to the adverse economic conditions.

5.2.1 Croatia

This subsection analyses possible future development of the specific–sector's default rates in Croatia. The baseline and adverse scenarios are employed. We estimate the default rates in the one year horizon, starting in the late 2010 and ending in the last quarter of 2011. We are particularly focused on the values of Q4 2011, which will be used as a measures of probability of default in the individual banks' credit portfolios.

Let us recall the regression equations for Croatian corporate and household sector credit risk models elaborated in Chapter 4. The dependent variables, the probabilities of default, will be expressed in terms of NPL ratio, previously denoted as npl_corp and npl_hh. From now, we symbolise them as PD_corp and PD_hh[15]:

$$ln\left(\frac{\widehat{PD}_{corp,t}}{1-\widehat{PD}_{corp,t}}\right) = -2.4229 - 3.6435 g\_hr_{t-4} + 0.0779 r_{t-4} + 3.5724 \pi_{t-3} + 1.0648 er\_usd_{t-2} + 0.2440 dum1_t + 0.3347 dum2_t + \epsilon_t \tag{5.2}$$

$$ln\left(\frac{\widehat{PD}_{hh,t}}{1-\widehat{PD}_{hh,t}}\right) = -3.0912 - 1.8276 g\_hr_{t-2} + 1.7730 u_{t-3} + 3.2625 \pi_{t-5} + 0.5417 dum1_t + 0.2026 dum2_t + \epsilon_t \tag{5.3}$$

where PD_corp_t and PD_hh_t are the banking sector's probabilities of default of loans provided to corporations and households, respectively. The GDP growth rate in Croatia is denoted by g_hr, r is the growth rate of the real interest rate, er_usd is the growth rate of the HRK/USD exchange rate, u is the growth rate of teh unemployment rate, π stands for the inflation measured by teh CPI and $dum1$ and $dum2$ are the dummy variables that adjust models for structural breaks that for 2011 have 0 values and thus do not influence the model.

We put the projected values from 2011 scenario analysis in the equation

[15] We are fully aware that the representation of the probabilities of default in terms of NPLs ratio is only an approximation that is used due to the lack of data on the probabilities of default.

Table 5.5: Credit risk macro stress–testing results for the actual, the baseline and the adverse scenarios in Croatia.

	Actual (%)	Baseline (%)	Adverse (%)
Corporate default rate	14.34	8.30	12.15
Relative to actual scenario	–	-42%	-15%
Household default rate	7.73	6.53	9.13
Relative to actual scenario	–	-15.5%	+18%

Source: Author's computations. The actual scenario refers to Q2 2010 and shows known values, the baseline and the adverse scenarios refers to Q4 2011.

(see Section 5.1.1) and we arrive at the sector–specific probabilities of default (PDs) for the adverse and the baseline scenarios in Croatia for the fourth quarter of 2011. Table 5.5 summarises the results and Figures 5.1 and 5.2 provide the graphical presentation of our findings, depicting the differences in PD's movements for both scenarios and sectors. The corporate sector probability of default is lower than the Q2 2010 value for both scenarios (8.3% and 12.15% for the baseline and the adverse scenarios in comparison to the 14.34 % probability of default in Q2 2010). In the baseline case this reflects the assumption of economic recovery in Croatia in 2011 that should positively influence the corporates' creditworthiness. In the adverse scenario the probability of default increases relative to the baseline scenario but it does not reach the 2010 level. Although we set the scenario to reflect the shock in the economy, the dependence of the macro credit risk model on the past values of the indicators causes that the full reflection of the shock will appear later.

In the case of households, the decrease of the probability of default in the baseline scenario (-15.5% is not so noticeable as in the case of firms (-42%). However, given the different time lag structure of the household's model, the impact of the adverse shock translates into the higher PD than was that observed in the past. Namely, the estimated credit risk model for the households reacts more swiftly on the GDP growth. Households do not profit from the appreciation of kuna against US dollar as firms do (see table 5.1). As a result the PD is by 18 % higher in the case of shock than the PD from Q2 2010.

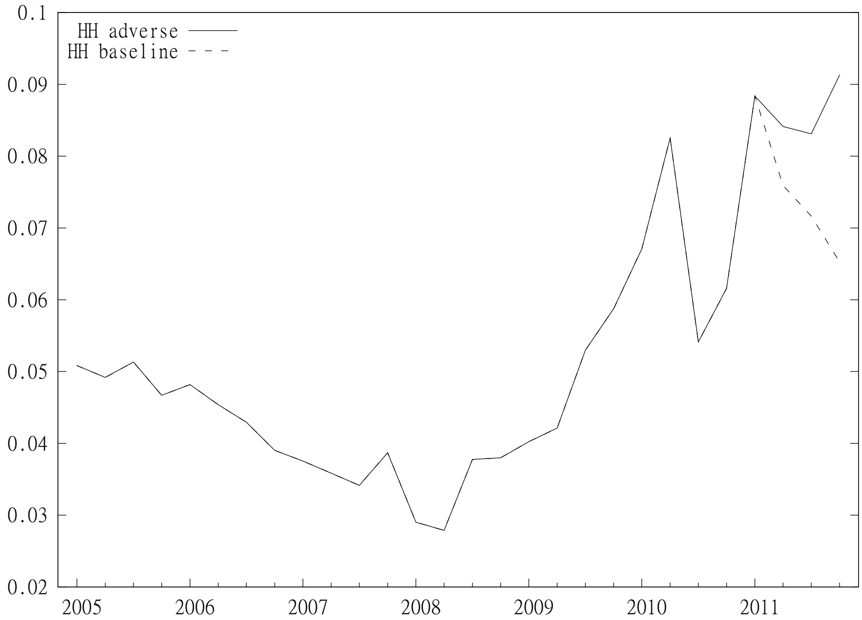
5.2.2 Serbia

In the case of Serbia, the projected sector–specific probability of default in the fourth quarter of 2011 for the baseline and adverse scenario is calculated, using

Figure 5.1: Baseline and adverse scenarios for the corporate sector in Croatia.

Source: Author's computations.

Figure 5.2: Baseline and adverse scenarios for the household sector in Croatia.



Source: Author's computations.

the estimated macro credit risk models in Chapter 4 and projected macroeconomic variables from the scenario analysis at the beginning of this chapter. The regression equations for the Serbian corporate and household sector elaborated in Chapter 4 now express the sector–specific probabilities of default. They are as follows:

$$ln\left(\frac{\widehat{PD}_{corp,t}}{1-\widehat{PD}_{corp,t}}\right) = -1.2588 - 1.2061g\_srb_{t-4} - 6.0872g\_eu_t \\ -1.0998er\_eur_{t-1} - 0.6843dum_t \tag{5.4}$$

$$ln\left(\frac{\widehat{PD}_{hh,t}}{1-\widehat{PD}_{hh,t}}\right) = -2.1873 + 1.1616er\_eur_t + 1.6337u_t \\ +0.5167i_{t-3} - 5.1918\pi_{t-4} - 0.1806dum_t \tag{5.5}$$

where PD_corp_t and PD_hh_t are the banking sector's probabilities of default of loans provided to corporations and households, respectively. The GDP growth rate in Serbia and the EU 15 are denoted by g_srb and g_eu, respectively. The growth rate of the RSD/EUR exchange rate is er_eur, u is the growth rate of the unemployment rate, i is teh growth rate of the nominal interest rate, π stands for the inflation measured by PPI and dum is dummy variable that adjust models for structural break, which is zero for 2011.

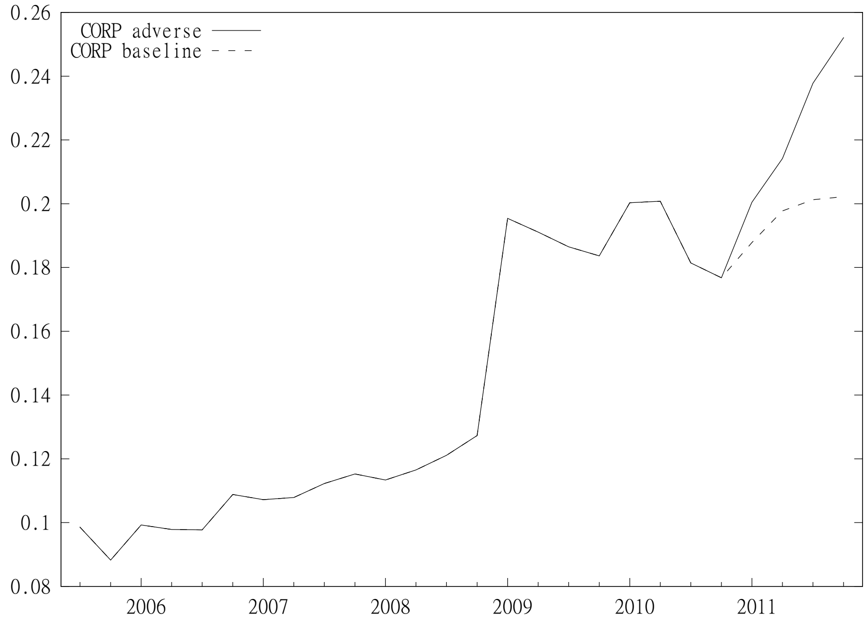
Table 5.6: Credit risk macro stress–testing results for the actual, the baseline and the adverse scenarios in Serbia.

	Actual (%)	Baseline (%)	Adverse (%)
Corporate default rate	19.63	20.22	25.21
Relative to actual scenario	–	+3%	+28%
Household default rate	7.81	4.78	6.58
Relative to actual scenario	–	-39%	-16%

Source: Author's computations. The actual scenario refers to Q3 2010 and shows known values, the baseline and the adverse scenarios refers to Q4 2011.

We utilise the data estimated in the scenario analysis for Serbia in Section 5.1 and we obtain the corporate and the household sector probabilities of default for the end of 2011. Table 5.6 shows the results. Contrary to the estimations in the Croatian case, the Serbian corporate sector demonstrates higher PDs both in the baseline and the adverse scenarios compared to the Q3 2011 values. The baseline scenario outcome can signal that firms are more rigid in the responses to economic changes in Serbia due to, for example, fixed contracts. Alternatively, the findings might indicate some difficulties in the corporate sector's repayment discipline that are still present, regardless the stage of the business cycle.[16] Figure 5.3 points out the possible stabilisation tendency at the end of the considered period for the baseline situation.

Figure 5.3: Baseline and adverse scenarios for the corporate sector in Serbia.



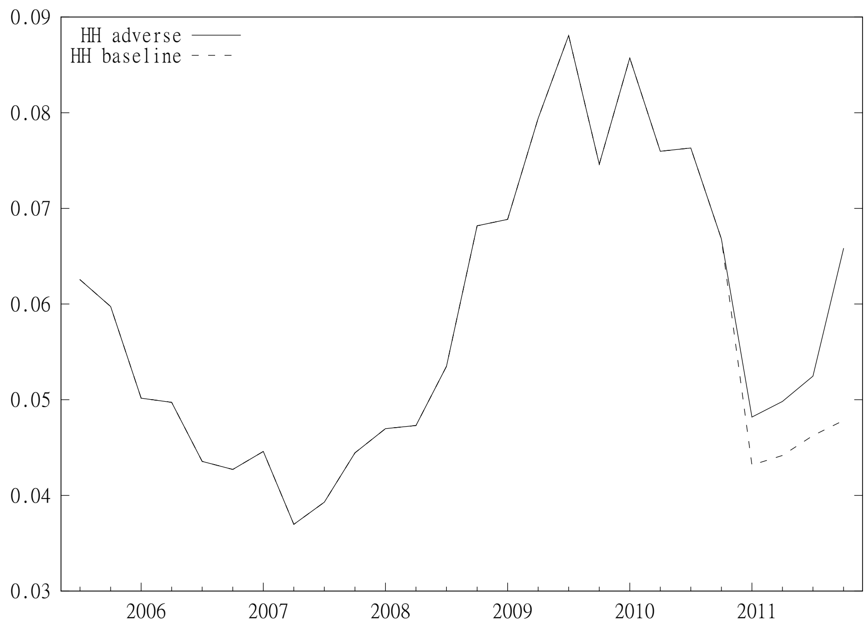
Source: Author's computations.

The household sector's PDs suggest the large decrease in the baseline situation (-39%) and the elevated decrease (-16%) in the case of the shock, demonstrating the opposite situation than that of firms. The lower PDs under the adverse scenario probably arise from the shape of the model where many variables are expressed in the lagged values. Especially, the inflation rate of 16% that enters the credit risk model of the household sector is elevated and favours Serbian households. The relative sensitivity of the model to the inflation further enhances the effect of the inflation (see Equation 5.5). All in all, promising economic conditions at the end of 2010 from the households' point of view causes households' PDs to decrease in both scenarios. Still, from the mid–2011 the

[16]Note that the increase in the PDs in the baseline scenario (+3%) is not very large, whereas in the adverse scenario an increase is much sharper (+28%).

PDs tend to increase. The question would be what values the PDs would reach in 2012 if the unfavourable conditions remained. Figures 5.3 and 5.4 show the evolution of the corporate and the household default rates for the baseline and the adverse scenario. The spread between the baseline and the adverse value at the end of the period is wider for firms than for households, with the difference of 5%, compared to around 2% for households.

Figure 5.4: Baseline and adverse scenarios for the household sector in Serbia.



Source: Author's computations.

5.3 Market Risk

This section provides the insight into the computation of market risk. The market risk is the risk of losses in the balance sheet and the off–balance sheet items caused by the changes in teh market prices. Basel II framework (see BCBS 2006) distinguishes the market risk into: 1) the interest rate risk of instruments and equities in the trading book, and 2) the foreign exchange rate risk and commodities risk. In our study we consider the interest rate and the exchange rate risks, both of which have direct and indirect impact on the banks' loan books. The indirect impact is, however, incorporated in the computation of the credit risk as it results from the impact of the changes in rates on the debtors' ability to repay the debt. Hence, we will explicitly assess only the direct impact of these two risks on the bank losses.

5.3.1 Interest Rate Risk

In our study the interest rate risk arouses from the marked–to–market bonds held by bank. The increase in interest rate causes the loss from holding these instruments. Apart from the original value of the bonds we employ the data on duration. The duration is according to FSI Compilation Guide (IMF 2006, paragraphs 3.51–3.56) the financial instrument's weighted average term to maturity. In our case the duration is approximated by the residual maturity, which is provided in the individual banks' financial statements.[17]

The interest rate losses are calculated as follows:

$$interest\ rate\ loss_{t+1} = V_t \times D_t \times \Delta ir_{t+1} \tag{5.6}$$

where V denotes the original value of the bond, D is the duration and Δir is the change in interest rate in time t. Čihák (2007) also consider another source of the interest rate risk–the maturity gap between interest sensitive assets and liabilities. However, we believe it is appropriate to calculate the gain or the loss from maturity gap as part of the interest income. The calculation is demonstrated in Section 5.3.3.

5.3.2 Foreign Exchange Rate Risk

The net open positions in the foreign currencies are subjects to the foreign exchange rate risk. FX risk is related to the changes in the exchange rate of domestic currency against individual foreign currencies. The net open position in the particular currency is defined as the net spot position plus relevant off–balance sheet derivatives. More specifically it is the sum of the value of assets held in foreign currency, minus the value of liabilities in that currency, plus the value of foreign currency financial derivatives. The calculation of the foreign risk loss arising from the exchange rate changes in the particular currency can be written as:

$$foreign\ exchange\ rate\ loss_{t+1} = -NOP_t \times \Delta er_{t+1} \tag{5.7}$$

[17]This definition is, however, valid only for the zero coupon instruments, but due to the lack of data and for the sake of simplicity we used it for all instruments. For an exact formula, see FSI Compilation Guide (IMF 2006).

where NOP denotes the net open position in the particular currency and Δer stands for the change of the exchange rate of the domestic currency against the given foreign currency in time t, all in domestic currency units.[18] For more detailed discussion about the calculation of the foreign exchange loss, see Čihák (2007, pp. 34–35).

5.3.3 Interest Income Projection

The calculation of the direct impact of the interest rate change on the bank's portfolio when the sensitivities of its assets and liabilities are mismatched can be found in Čihák (2007). We assess the impact of the interest rate change on the interest income and expenses. The net inflow of interest arises from the maturity gap between the inflow of interest from holding assets and outflow of interest on the liability side of the balance sheet. If the maturity gap is positive then the increase in the interest rates leads to the gains that appear as a part of the interest income in the income statement. In the next chapter we will add these gains to the profit as a part of the buffer for potential losses. The interest rate gain is calculated as follows:

$$interest\ rate\ gain_{t+1} = G \times \Delta ir_{t+1} \tag{5.8}$$

where G is the cumulative maturity gap between the interest sensitive assets and liabilities and Δir is the change in the interest rate in time t. When the interest rate increases, the positive maturity gap results in the gains from the interest rate change and vice versa.

In the following chapter we will apply derived equations on the individual banks' portfolios in Croatia and Serbia. We will the calculate capital adequacy ratio (CAR) for the baseline and the adverse scenario for the individual banks and we will discuss possible policy implications arising from our findings.

[18] Note that we express the exchange rate in the units of domestic currency per the unit of foreign currency throughout the study. Thus, the positive exchange rate change signals the depreciation of the domestic currency, which translates into the FX gain if the net open position is positive. As we defined the dependent variable as the foreign exchange rate risk loss, we put the negative sign on the right side of the equation. Then the negative loss expresses the gain. The similar approach will be used in the next chapter in order to assess the exchange rate risk in individual banks' portfolios.

Chapter 6

Stress Testing Results

6.1 Overall Banking Sector Environment

This chapter illustrates the application of the stress testing on the individual banks in Croatia and Serbia. For this purpose, we used macroeconomic factors from the end of 2010 and we projected their values for the last quarter of 2011 under the baseline and the adverse scenario (see Chapter 5). The banks represent the major part of the banking sectors in Croatia and Serbia. In order to estimate the impact of the scenarios on the banks' performance in 2011, we approximated the banks' 2010 financial results by the data derived from the end of 2009. This approximation was necessary due to the delays in submitting the banks'financial reports.[1].

In Croatia, the total banking system's (BS's) assets in 2009 were 378.4 billion HRK. In our analysis, we have chosen the 9 biggest banks that account for 92.6% of the total banking system's assets. According to the ownership structure, there were 15 foreign–owned banks (90.9% of the BS's assets), 17 private domestic banks (4.9% of total BS's assets) and 2 state–owned banks (4.2% of total BS's assets).

In Serbia, the total BS's assets in 2009 were 2 160 billion RSD. We investigate the 10 biggest banks, which account for 70% of the total BS's assets. Regarding the ownership structure, there were 20 foreign–owned banks (74.3% of total BS's assets), 4 private domestic banks (8.2% of total BS's assets) and 10 state–owned banks (17.5% of total BS's assets) in Serbia. The selected

[1]The financial reports were obtained from the database Bankscope, available at http://www.bvdinfo.com. If the data were not available in Bankscope, we utilise the individual financial reports of the banks.

banks are either medium–sized or large banks.[2] The portion of selected banks' assets to the total BS's assets suggests that the Serbian banking sector is less concentrated than the banking sector in Croatia. Tables 6.1 and 6.2 provide the description of the Croatian and the Serbian banking systems.

Table 6.1: Assets and ownership structure of the selected banks in Croatia (in HRK billion).

	Total BS	9 selected banks	Selected banks in % of total BS
Assets	378	348	91.9
Number of FB	15	8	53.3
Assets of FB	344	334	97.0
Number of PB	17	0	0.00
Assets of PB	19	0	0.00
Number of SB	2	1	0.5
Assets of SB	16	14	88.0

Source: Author's computations. Data are from the CNB's on–line database and of the end of 2009. BS is banking system, FB, PB and SB denote foreign–owned, private domestic–owned and state–owned bank.

6.2 Stress Testing of the Individual Banks

In this section we set up the equations for the calculation of the bank's capital adequacy ratio (CAR). The losses from the individual risks are computed according to the models provided in Sections 5.2 and 5.3 in Chapter 5. The bank's capital adequacy ratio (CAR) in time $t+1$ can be expressed as follows:

$$CAR_{t+1} = \left(\frac{Cap_t + Profit_{t+1} - Credit\_loss_{t+1} - Market\_loss_{t+1}}{RWA_t - \Delta NPL_{t+1}} \right) \tag{6.1}$$

where Cap is the regulatory capital. Bank's profit $Profit$ is the last 3–year average net income[3] plus the net interest rate gain/loss from the movements in the interest rates, calculated in Equation 5.8 in Chapter 5. Variable $Credit\_loss$

[2]Size of the bank is defined in terms of the amount of bank's assets relative to the total banking system' assets. The small bank is the bank with the assets' share of less 1% of the total assets, the medium-sized bank's assets range from 1% to 5% of the total assets, and the large bank's assets account for more than 5% of the total assets.

[3]Alternatively, we can use the net income of the last available year.

Table 6.2: Assets and ownership structure of the selected banks in Serbia (in RSD billion).

	Total BS	10 selected banks	Selected banks in % of total BS
Assets	2 160	1 512	70.0
Number of FB	20	8	40.0
Assets of FB	1 605	1 184	73.7
Number of PB	4	1	25.0
Assets of PB	177	109	61.7
Number of SB	10	1	10.0
Assets of SB	378	219	58.0

Source: Author's computations. Data are from the NBS's Fourth Quarter Report (2009) and of the end of 2009. BS is banking system, FB, PB and SB denote foreign–owned, private domestic–owned and state–owned bank.

is the credit risk loss expressed in Equation 5.1, $Market\_loss$ is the market risk loss that arise from the movements in the interest rate and foreign exchange rates (Equations 5.6 and 5.7), RWA are the risk–weighted assets and ΔNPL is the inflow of new NPLs with the risk weight of 100%.[4]Time t represents the end of 2010, however the banks' data are from the end of 2009 as was discussed above. We implicitly assume, that bank keeps all its profit and does not distribute it among shareholders, which might not be true in reality, especially if the gained profit is large. However, the estimation of the amount of retained profit is not usually available. The assumption might lead to elevated values of the CAR. Some banks' results provide the large CARs, i.e. 30–50% (see Tables 6.3 and 6.4). In reality the values could be lower if we assumed the part of the profit was redistributed.

The RWA are reduced by the inflow of new NPLs. It is the consequence of the increase in provisioning requirements that the bank should undertake when the NPLs are increasing (see Čihák 2007, p. 29). A common assumption is that the increase in NPLs will be fully subtracted from the RWA. In reality, the choice of the risk weights depends on the distribution of the NPLs across the categories of risks of assets. This information is usually not available.

[4]The risk weight of 100% for the NPLs is the commonly accepted approximation and it was used i.e. in Čihák (2007).

According to Jakubík & Sutton (2011) the inflow of new NPLs can be expressed as:

$$\Delta NPL_{t+1} = NPL_{t+1} - NPL_t \tag{6.2}$$

$$NPL_{t+1} = NPL_t + PD_t \times (Loans_t - NPL_t) - r \times NPL_t \tag{6.3}$$

where PD is the probability of default, $Loans$ are the current loans in the portfolio, and r is the average write–off (or sell–out) rate of existing NPLs. We have estimated the default probability for the corporate and the household sectors separately. All variables that enter Equation 6.1 are divided according to sector to which they refer. In the final computation we add all partial results together. The write–off rates varied extremely across the institutions and over time. In 2009, some institutions wrote off only a subtle part of their loans. Hence, in 2010, we supposed they might increase the write–offs (see Table C.1 in Appendix C). In order to unify the conditions of banks and to set them in the realistic fashion, we use the average write–off rate of and we employ it on all banks

6.3 Results

This section provides the stress–testing results of the 9 largest banks in Croatia and the 10 largest banks in Serbia. In terms of assets, the banks cover the 92% and 70% of the size of the banking sector in Croatia and Serbia, respectively. Although we use the real banks' data that are publicly available, we decided not to explicitly identify the banks. This study aims to illustrate the application of the stress tests to the real banks' portfolios and to reveal the possible threats to financial stability in the given countries, not to provide the implications to the individual banks. Also for the sake of simplicity we provide the banks with the letters in an alphabetical order.

Before we provide the results of the stress tests run on the individual banks we should discuss some modifications that we have done in the bank's sample. In some banks, not all necessary data were available. In that case we approximated them or we made some simplifying assumptions. Particularly, we assumed for all banks that their net open positions are all in euro due to the limited information on all open positions. This assumption does not distort the results a lot as the foreign exchange rates are usually highly correlated (for illustration, see correlation matrices in Appendix B). Similarly, we approximated banks' NPLs by the impaired loans, as data on the NPLs were not available in the major part of the banks. Again, there is a high correlation between the NPLs and impaired loans because the impaired loans are the part of the NPLs. Some data were available only on the consolidated basis in the database Bankscope. It concerns the one bank in Croatia and the three banks in Serbia. In that cases, however the bank's operations represented the major part of the group's financial statements, thus the approximation does not disturb the real conditions heavily.

For the Bank D in Croatia we approximated the regulatory capital and risk–weighted assets by averaging other banks' regulatory capital/RWA and total capital/total assets, dividing them and multiplying the particular bank's total capital/total assets with the obtained coefficient (see Table 6.3). The same procedure applied in Serbia for the Banks E and H (see Tables 6.3 and 6.4). Next, for the Bank F in Croatia the data on available–for–sale securities were not provided and we did not assume them in the computations. As a consequence, this bank does not show any losses from the interest rate movements and its CAR can be overestimated. Similarly, there were not data on the net open positions of the Bank H and we did not compute the loss or the gain from the change in the exchange rate. Finally, the Bank G did not report its maturity gap analysis for the interest rate risk. The possible gains or losses were not added to the regulatory capital in the CAR computation. In the case of Serbia, there were not data on the maturity gap for the Bank D.

The results of the stress tests are demonstrated in Table 6.3 for the Croatian banking sector and in Table 6.4 for the Serbian banking sector. The results depend on the considered scenarios and models, therefore the outcome can change easily if we change some assumptions. The capital adequacy ratios are provided for the initial situation, the baseline scenario and the adverse scenario. In both countries the regulatory minimum CAR is set by the national banks on the level of 12%.[5]

[5] The threshold of 12% is relatively elevated in comparison with the other banking sectors. In the EU the CAR's threshold is 8%.

Table 6.3: Stress–testing results for the banks in Croatia (in HRK million).

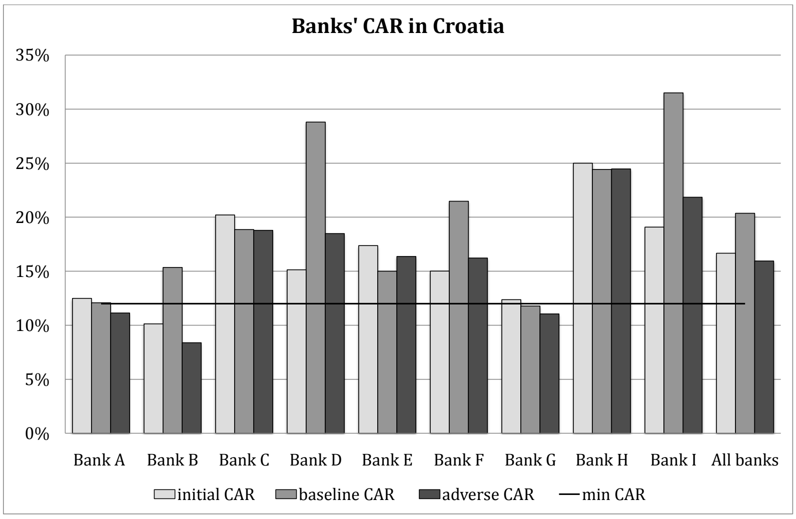
	Bank A*	Bank B	Bank C	Bank D	Bank E	Bank F	Bank G	Bank H	Bank I	All banks
Total assets	50 440	13 981	38 499	12 545	64 519	39 499	27 621	7 640	92 812	347 556
Bank size	L	M	L	M	L	L	L	M	L	
Ownership	FB	SB	FB	FB	FB	FB	FB	FB	FB	
Reg. capital$_t$	5 094	1 012	8 334	1 595**	9 080	4 993	3 050	1752	13 587	48 497
RWA$_t$	40 803	9 983	41 232	10 538**	52 285	33 255	24 664	7 010	71 180	290 950
CAR$_t$(%)	12.48	10.13	20.21	15.14	17.37	15.01	12.37	24.99	19.19	16.67
Baseline										
ΔNPL_{t+1}	2 000	108	1 446	475	1 586	1 703	1 155	251	3 234	11 951
Est. profit$_{t+1}$	705	-106	140	114	986	432	291	59	1 240	3 860
Credit risk loss	1 111	235	919	266	1 357	816	609	160	2 002	7 473
Market risk loss	1	-845	51	-1 456	1 103	-2 168	-38	N/A	-8 587	-11 938
CAR$_{t+1}$(%)	12.08	15.35	18.86	28.81	15.00	21.48	11.78	24.42	31.51	20.37
Adverse										
ΔNPL_{t+1}	3 074	247	1 984	669	2 375	2 259	1 551	363	4 421	18 641
Est. profit$_{t+1}$	826	-111	265	206	1 145	536	291	92	1 366	4 616
Credit risk loss	1 596	298	1 175	354	1 770	1 062	788	212	2 572	10 744
Market risk loss	121	-214	50	-376	289	-561	-1	5	-2 206	-1 058
CAR$_{t+1}$(%)	11.14	8.39	18.79	18.48	16.36	16.22	11.05	24.47	21.85	15.95

Source: Author's computations. L=large bank, M=medium–sized bank, S=small bank. FB, PB and SB denote the foreign–owned, the private domestic–owned and the state–owned bank. The initial CAR refers to the end of 2010, the baseline and the adverse CARs to the end of 2011. The negative sign in the row that provide the estimated losses signifies the gain from the change in the given rate. From April 1, 2010, the regulatory minimum CAR is 12%. For the CAR at the end of 2009 the regulatory minimum was 10%.

* Data for whole Group. ** Data estimations.

In the case of Croatia, we consider the six large banks with the individual total assets accounting for more than 5% of the total BS's assets. There are also three medium–sized banks with the asset share in the range between 1% and 5% of the total assets in the banking system. Under the initial scenario that describes the situation in the end of 2010 there is one bank with the CAR lower than the regulatory minimum requirement (Bank B). Given that these values are actually from 2009 and that the CNB raised its minimum CAR requirements in April 2010, this bank formally did not violate the requirements. The highest CAR reaches almost 25% (Bank H). The majority of banks demonstrate the ratio below 20%. Three banks with the lowest values demonstrate the lowest CARs also under the baseline and the adverse scenarios. The banks' CARs under the initial, the baseline and the adverse scenarios are lined up in Figure 6.1.

Figure 6.1: Banks' CAR according to the scenario in Croatia.



Source: Author's computations.

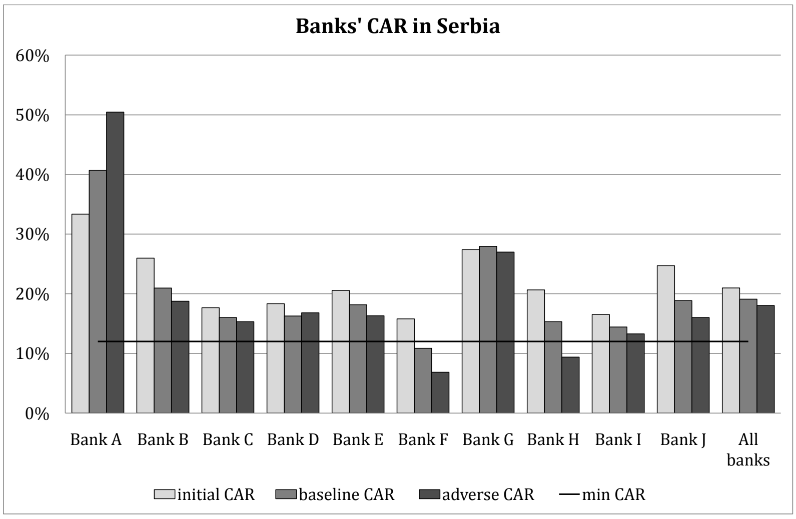
All Croatian banks show the positive profits apart from the Bank B. The loss of the Bank B is caused by the relatively large loss in the last reported year and by the loss from the maturity gap between the interest sensitive assets and liabilities. Although the gains of the Bank B from the market prices changes are almost the same as the credit risk losses the bank's CAR deteriorates under the adverse scenario (from 10.13% to 8.39%) and falls below the regulatory threshold. Accordingly, the Bank A and the Bank G slightly fall below the

Table 6.4: Stress–testing results for the banks in Serbia (in RSD million).

	Bank A	Bank B	Bank C	Bank D	Bank E*	Bank F	Bank G	Bank H*	Bank I	Bank J	All banks
Total assets	109 422	73 650	307 939	146 840	138 923	219 355	193 517	99 711	135 768	87 113	1 512 237
Bank size	M	M	L	L	L	L	L	M	L	M	
Ownership	PB	FB	FB	FB	FB	SB	FB	FB	FB	FB	
Reg. capital$_t$	28632	12 680	46 232	18 792	25 610**	25 096	47 248	16 562**	20 944	13 445	255 240
RWA$_t$	85 850	48 814	261 630	102 510	124 583	158 792	172 374	80 172**	126 785	54 395	1 215 904
CAR$_t$(%)	33.35	25.98	17.67	18.33	20.56	15.80	27.41	20.66	16.52	24.72	20.99
Baseline											
ΔNPL_{t+1}	4 222	2 756	17 219	6 342	11 576	15 011	4 781	8 025	12 893	174	82 901
Est. profit$_{t+1}$	5 441	-608	6 324	2 714	1 710	2 406	5 094	1 857	2 616	1 083	28 637
Credit risk loss	5 329	2 342	13 656	7 326	6 690	10 661	5 049	5 811	7 304	3 914	68 395
Market risk loss	-4 470	78	-249	-1 478	105	1 218	453	1 551	-200	386	-823
CAR$_{t+1}$(%)	40.69	20.95	16.02	16.28	18.16	10.87	27.95	15.33	14.45	18.86	19.09
Adverse											
ΔNPL_{t+1}	6 099	5 479	25 666	10 015	16 451	21153	7 153	10 980	17 308	1 331	121 338
Est. profit$_{t+1}$	5 671	-678	7 628	2 714	1 733	2 158	5 516	2 021	2 700	1 214	30 677
Credit risk loss	6 763	3 661	18 453	10 156	9 424	14 368	6 901	7 699	9 758	5 071	92 571
Market risk loss	-12 687	210	-745	-4 209	272	3 452	1 267	4 384	-672	1 093	-4 142
CAR$_{t+1}$(%)	50.44	18.76	15.32	16.82	16.32	6.85	26.99	9.39	13.30	16.01	18.04

Source: Author's computations. L=large bank, M=medium–sized bank, S=small bank. FB, PB and SB denote the foreign–owned, the private domestic–owned and the state–owned bank. The initial CAR refers to the end of 2010, the baseline and the adverse CARs to the end of 2011. The negative sign in the row that provide the estimated losses signifies the gain from the change in the given rate. Regulatory minimum CAR is 12%.
* Data for whole Group. ** Data estimations.

Figure 6.2: Banks' CAR according to the scenario in Serbia.



Source: Author's computations.

threshold level under the adverse scenario. Four of nine banks experience the gains from the interest rate and the foreign exchange rate movements under the scenarios, even though under the adverse scenario the gains are lower. Under the baseline scenario, the aggregate market risk gain (the column "all banks" in Table 6.3) is of 60% higher than the loss from the credit risk (in absolute values). The significance of the market risk share relative to the credit risk share in the CAR noticeably declines under the adverse scenario.

The approximated Serbian sector consists of the six large banks and the four banks of the medium size. The initial situation demonstrates the elevated CARs for all banks. The elevated CARs could suggest that the banks in Serbia might be very conservative and might keep a large capital buffer against the potential losses. One of the banks experiences the drop below the regulatory CAR requirement (Bank F) in the baseline scenario and two banks fall below the threshold under the adverse scenario (Bank H and Bank F). The Bank A demonstrates the highest CAR under all scenarios.[6] The high value of the CAR in the Bank A can results from the relatively favourable net open FX positions and the large profits. The Bank A is the only bank in the Serbian banking

[6]Note that we assume that banks keep the profits and do not redistribute them between the shareholders. It is not unlikely that the Bank A with the CAR of more than 40% would redistribute at least the part of its profit. In reality, the CAR of the Bank A could be lower.

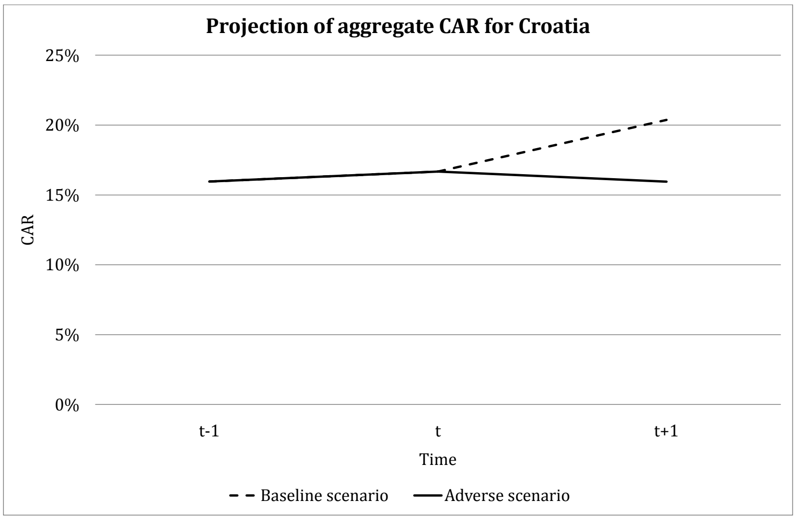
sector's sample that shows the higher share of the market risk gain/loss to the regulatory capital in comparison to the credit risk loss share to the regulatory capital. The other banks do not involve in the market risk operations a lot. It is noticeable relative to the Croatian banks' market risk results. The aggregate CAR shows the relatively high values under all scenarios. The banks' CARs under the initial situation, the baseline and the adverse scenarios are lined up in Figure 6.2.

The results of the movements in the market prices of the FX positions or the bonds can significantly vary across the scenarios. The "good" positions in the FX or the bond market can favour banks and can create the gains. But the market position are an unstable source of the gain because they highly depends on the situation on the financial markets that is continuously evolving. For illustration, Figures C.1, C.2, C.3 and C.4 in Appendix C demonstrate the relative significance of the credit risk loss, the interest rate loss and the foreign exchange rate loss in terms of the regulatory capital according to the scenario. The interest rate risk does not appear to be significant neither under the baseline nor adverse scenario but the relative significance of the credit risk and the foreign exchange rate risk changes according to the employed scenario.

Under the baseline scenario (Figure C.1 in Appendix C) the four Croatian banks out of nine demonstrate the higher portion of the foreign exchange rate risk gains to the capital than is the portion of credit risk losses to the capital. The relative instability of the gains or the losses from the net open FX positions is illustrated in Figure C.2 in Appendix C. Under the adverse scenario the gains are much smaller (accounting for about 8% of the regulatory capital, compared to the more than 20% of the regulatory capital under the baseline scenario). On the other hand, the losses from the credit risk increase slightly under the baseline scenario (from the less than 20% to the more than 20% of the regulatory capital). In the case of the Serbian banks the market risk gains/losses are significant only in a few banks and only the Bank A shows higher portion of the FX gain than of the credit risk loss relative to the regulatory capital under adverse scenario (see Figures C.3 and C.4 in Appendix C).

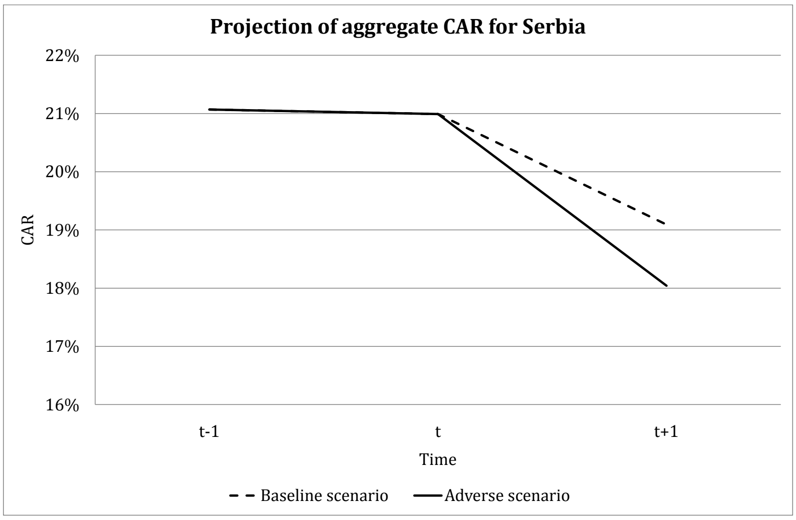
Figures 6.3, 6.4, 6.5 and 6.6 demonstrates the evolution of the banks' aggregate CAR and aggregate NPL ratio in Croatia and Serbia under the baseline and the adverse scenarios. The three year horizon is applied. The time t denotes the year 2010. In the case of Croatia the aggregate CAR under the baseline scenario increases, whereas under the adverse scenario it slightly decreases. In the case of Serbia, the CAR decreases under the both scenarios.

Figure 6.3: Aggregate banks' CAR according to the scenario in Croatia.



Source: Author's computations.

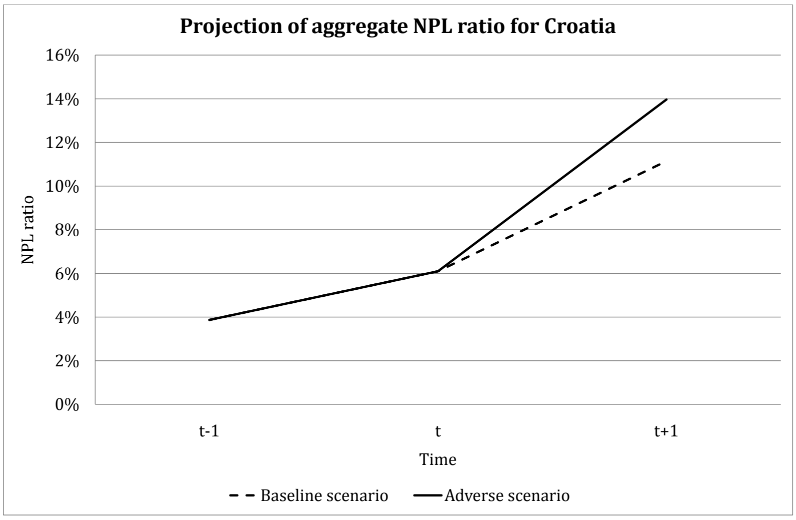
Figure 6.4: Aggregate banks' CAR according to the scenario in Serbia.



Source: Author's computations.

The figures that depict the development of the NPL ratio show that the NPL ratios increases rapidly in the both countries under the both scenarios. The sample period is relatively small but the evolution of the variables might signal that there could be the tendency of the increasing non–performing loans relative to the total loans in Croatia and Serbia. Accordingly, the evolution of the CARs points out the decreasing trend.

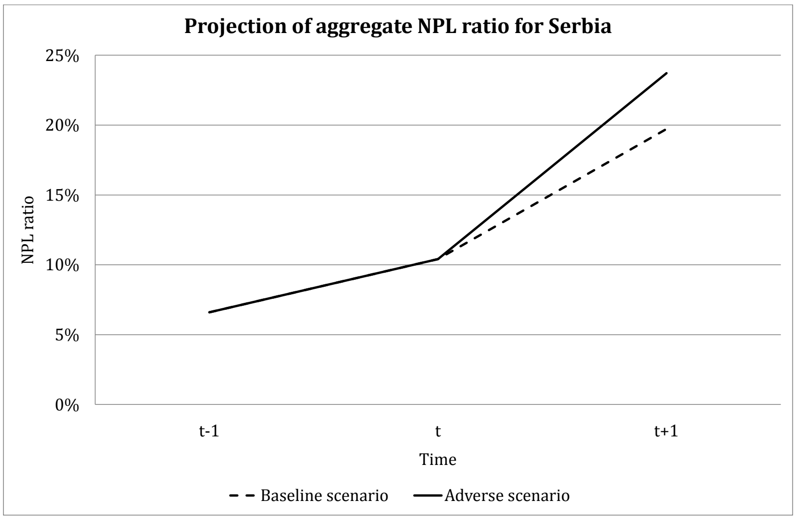
Figure 6.5: Aggregate banks' NPL ratio according to the scenario in Croatia.



Source: Author's computations.

The stress test results on the individual banks' level demonstrate the impact of the shock that is translated into the credit and the market risks and expressed in terms of the CARs. We provide the estimation of the overall impact as well as its decomposition into the individual risks. The tables and the figures provide the individual banks'results as well as the aggregate banking sector's results that is represented by the selected banks. In overall, the stress–testing results confirm that the banking systems in Croatia and Serbia are robust and able to withstand both the most likely future conditions and the economic deterioration. Only a minor part of the banks face difficulties with fulfilling of the minimum CAR requirements. On the other hand, the ' CARs of particular banks are elevated and that indicates that these banks could redistribute the profit and lower the capital buffer. In the next section we will discuss some policy implications that arise from the stress–testing results.

Figure 6.6: Aggregate banks' NPL ratio according to the scenario in Serbia.



Source: Author's computations.

6.4 Policy Implications

The estimation of the CARs of the major banks in Croatia and Serbia and their comparison to the regulatory minimum CAR allow us to assess the banking sector stability in each country. As Čihák (2007, p. 53) argues, the CAR does not capture all possible macro effects that arise from the simulated shocks but it can indicate potential fiscal costs of preventing the banks to fail. It is relevant to consider whether the particular bank is state–owned, private–owned or foreign–owned bank. The government would most likely bail–out the state–owned banks if they failed. But it is uncertain whether the government would help also the private and the foreign banks that faced the distress. For the banks that belong to the group "too big to fail", the government usually does not have any other option than to provide them with the capital injection. The size of the bank and its ownership structure is particularly important in our study due to the fact that the major part of the banking sectors in Croatia and Serbia is controlled by the foreign banks.

Section 6.3 revealed the banks that cannot withstand the economic conditions under the baseline and the adverse scenarios. Table 6.5 indicates the amount of additional resources that would be necessary to inject in the institutions (usually in form of the capital) in order to bring their CARs to the minimum regulatory level. Under the baseline scenario the potential injection that would be needed for the stressed bank accounts for 0.016% and 0.06% of domestic GDP in Croatia and Serbia, respectively.

Under the adverse scenario the amount of the capital needed increases of 844 million HRK in the case of Croatia and of 7 255 million RSD in the Serbia case (see Table 6.5). The values of the injections correspond to the 0.27% share of the GDP in Croatia and the 0.33% share of the GDP in Serbia. In terms of the ownership structure the undercapitalised banks in Croatia are two foreign banks and one state–owned bank. The undercapitalised banks in Serbia are one foreign and one state–owned bank.

Table 6.5: Injection needed to meet the minimum CAR (in mil. of national currency).

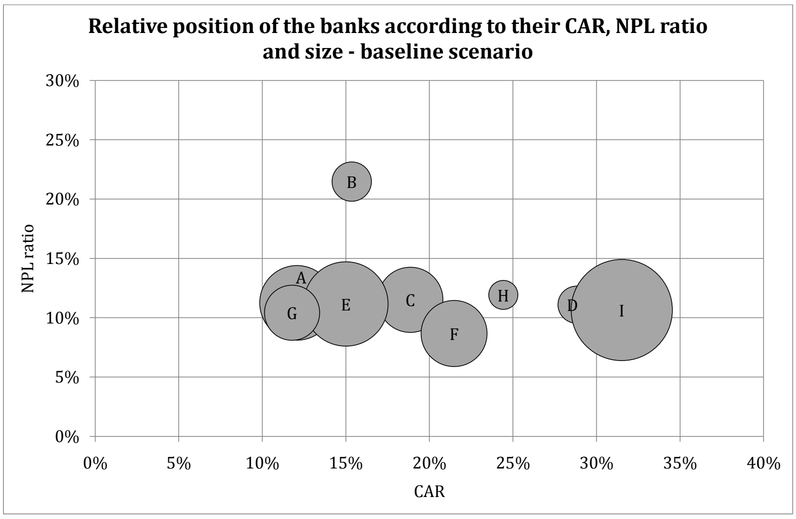
Scenario	Croatia Baseline	Croatia Adverse	Serbia Baseline	Serbia Adverse
Bank A	No need	324.6	No need	No need
Bank B	No need	351.7	No need	No need
Bank C	No need	No need	No need	No need
Bank D	No need	No need	No need	No need
Bank E	No need	No need	No need	No need
Bank F	No need	No need	1 630.6	7 082.4
Bank G	52.0	219.8	No need	No need
Bank H	No need	No need	No need	1 803.4
Bank I	No need	No need	No need	No need
Bank J	–	–	No need	No need
Total	52.0	896.1	1 630.6	8 885.7
Share of GDP_{2009}	0.016%	0.267%	0.060%	0.327%

Source: Author's computations. Currencies: Croatian kuna and Serbian dinar. Share of GDP: total injection needed as a portion of domestic GDP. Data on GDP are in current prices of 2009 because 2010 values were not available yet. Note that the capital injection is calculated without reflecting any developments affecting the banks' capital or its structure since the end–2009.

Figures 6.7, 6.8, 6.9 and 6.10 provide an interesting insight into the relative position of all banks according to the level of their CAR, NPL ratio and size. The NPL ratio represents the portion of NPLs to the total loans in time $t+1$ and bank size is set in terms of the bank's assets to the total banking sector's assets.

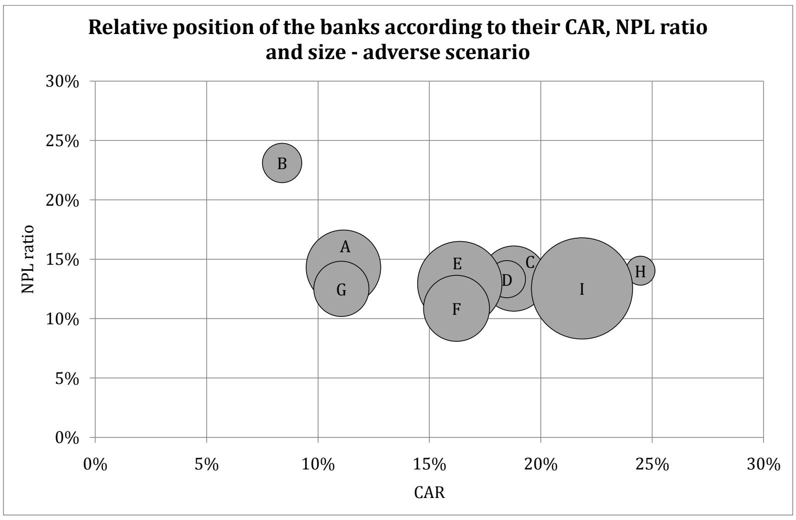
The banks in Croatia demonstrate similar positions in terms of the NPL

Figure 6.7: Bubble chart of the NPL ratio, the CAR and the asset share for the baseline scenario in Croatia.



Source: Author's computations.

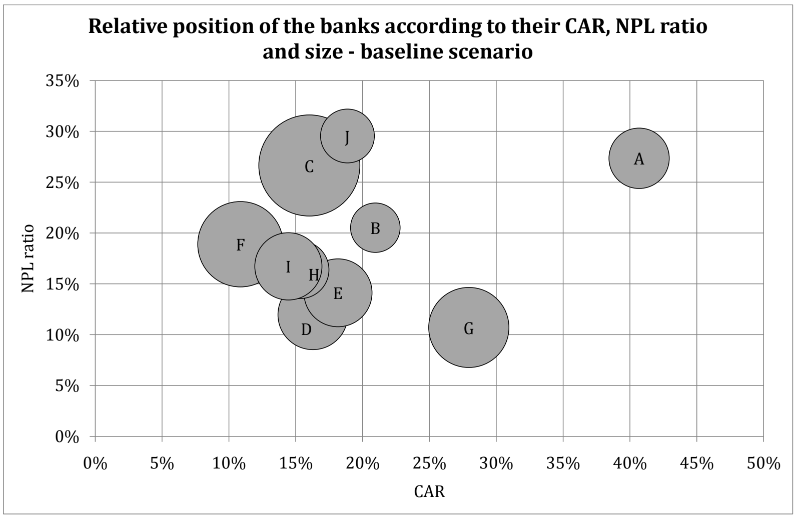
Figure 6.8: Bubble chart of the NPL ratio, the CAR and the asset share for the adverse scenario in Croatia.



Source: Author's computations.

ratio. They vary in the CAR values (Figures 6.7 and 6.8). We can distinguish the two banks that are relatively close to the 12 % CAR bound under the baseline scenario and three banks that are below this threshold under the adverse scenario. One of those banks is large compared to the other banks, the second one is medium–sized and the third one belongs to the group of smaller banks (specifically Banks A, B and G). The Banks A and G are the foreign–owned institutions and the Bank B is the state–owned bank. If the banks were about to fail, the government would take the steps to maintain the financial stability in the country. Most likely the government would bail–out the state–owned Bank B that is the smallest bank under the distress but with the largest amount of missing capital. Bank A is relatively large bank in the banking system and it would be unlikely that the government would let the Bank A to fail. The question could be what would happen with the Bank G that is neither "too big" nor state–owned, and under the adverse scenario it could demand the injection of almost 220 million HRK.

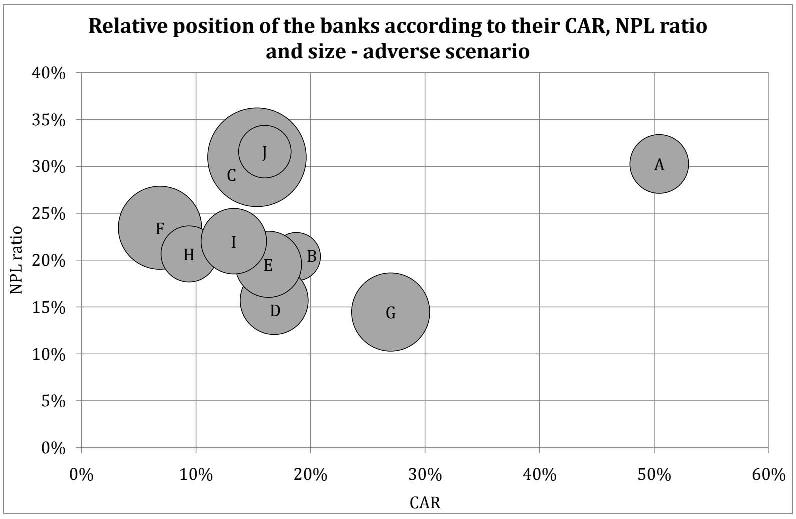
Figure 6.9: Bubble chart of the NPL ratio, the CAR and the asset share for the baseline scenario in Serbia.



Source: Author's computations.

In the case of Serbia, the banks are dispersed both in terms of the NPL ratio and the CAR (Figures 6.9 and 6.10). Relatively large Bank F can be found below the threshold of 12% under the both scenarios. Moreover, under the adverse scenario, Bank H also falls below the threshold. The banks below

Figure 6.10: Bubble chart of the NPL ratio, the CAR and the asset share for the adverse scenario in Serbia.



Source: Author's computations.

the 12 % CAR bound in Serbia are one state–owned and one foreign–owned bank. In the Serbian case the larger bank is the state–owned, which we believe would be bailout in the case it failed. The situation of the relatively small foreign–owned Bank H is uncertain. In order to bail–out both banks under the adverse scenario, the Serbian government would need the injection of 8 886 million RSD. It represents the 0.33% share of domestic GDP. In comparison with the Croatian case (0.27%), the share of GDP in Serbia that would be needed to bailout the banks under the adverse scenario is slightly higher.

Both the adverse and the baseline scenarios are constructed as "what if" scenarios. We aimed to assess the capital buffer that would help to prevent banking failures if one of the scenario occurred. We do not assess the probability that these scenario will occur. As for the banks in the Croatian and Serbian banking sectors that proved enough level of CAR under the both scenarios, the stress tests can confirm their robustness and capacity to absorb losses, as well as the overall financial health of the economies.

Chapter 7

Conclusion

This thesis reviewed the macro stress–testing methodology and applied it on the real aggregate and the individual bank's data in Croatia and Serbia. The aim of the study was to answer the questions whether we are able to build the macro stress–testing framework using the publicly available data for Croatia and Serbia and whether the stress tests can reveal possible risks to the individual banks and the threats to the financial stability in the countries. The outcome of the study demonstrates that even with limited data the consistent stress tests could be developed under the simplifying assumptions. In Chapter 6, we have shown there are some banks that can have problems with fulfilling the regulatory minimum capital requirements both under the baseline and the adverse scenarios. Accordingly, the calculated capital injection that should prevent banks from possible failures reflects the potential fiscal costs to the government.

The baseline and the adverse scenarios were set to project the macroeconomic variables for the end of 2011. The baseline scenario described the most likely future situation using the various macroeconomic forecasts. The adverse scenario reflected the situation that occurred during the recent crisis, thus, the data originated in 2008–2010. The macro stress tests were constructed in such a way that they capture the linkage between the macroeconomic factors (GDP growth, inflation rate, interest rate etc.) and banks' balance–sheet items through the macro credit risk models, which were based on Wilson (1997a,b) approach. The models expressed the dependent variable in the logistic function form. For each country the models were developed for the corporate and the household sectors separately, reflecting the sectors' diverse sensitivities to the various macro factors. These satellite models estimated the sector–specific default rates (expressed in terms of the non–performing loans to the total loans) for the end of 2011 using the past data and 2011 macro forecasts. The default rates were then used for the calculation of the individual banks' losses that arose from the credit risk exposures. For each bank we estimated also the market risk losses. Banks' balance–sheet data were those of 2009 due to the time lag in their publishing. Both losses entered in the computation of the capital adequacy ratios (CARs) under the baseline and the adverse scenario in the end of 2011.

In the case of Croatia, we considered the nine largest banks that accounted for more than 90% of the total banking sector assets in 2009. Under the baseline scenario we detected one foreign–owned large bank that had the CAR below the regulatory minimum level of 12%. Under the adverse scenario, there emerged two more banks with the CAR below the threshold, one of them was medium–sized state–owned bank and the second one was large foreign–owned bank. Under the adverse scenario, the estimated capital injection that would be needed to bring these banks to the level of CAR of 12% amounted for almost 0.27% of the 2009 GDP in Croatia. In Serbia, we analysed ten major banks that accounted for 70% of the banking sector assets in 2009. Similarly to the situation in Croatia, there was one state–owned bank that did not fulfil the capital requirements under the baseline scenario and two banks (large state–owned and medium–sized foreign bank) with the same difficulties under the adverse scenario. In terms of the share of GDP the estimated capital injection was larger than in the case of Croatia, accounting for 0.33% of the Serbian GDP in 2009.

The stress tests are useful tools for the regulators and supervisors as they can reveal potential threats to the financial stability. However, we should bear in mind that the results should be interpreted with caution as we faced data limitation and relatively short time series when we were constructing the models. On the other hand the model set in the thesis is relatively simple and intuitive and can be further developed when more data are available so that it becomes more robust.

The thesis contributes to the current stress testing literature by analysing the countries that are not frequently considered in the stress tests and by covering periods prior to, during and after the recent financial crisis. As the large part of surveys conducted the stress tests before the crisis has emerged, recent data can show new and interesting results. Also, the simple framework provided in the study can be applied on other emerging markets that face similar data limitations.

Possible extensions for the future research lie in the broadening the range of risks that could be considered in the stress–testing framework, especially by adding the liquidity tests and the contagion analysis. The time horizon might be prolonged from one up to three years so that the shocks can fully translate into the deterioration of the financial performance of the banks and the whole system. In line with it, the attention should be paid to the problems of the endogeneity of risk and the feedback effects. Next, it might be useful to revise the theoretical models and variables if more data are available in order to check the models for parameters' instability and increase their predictive power. Finally, in the future the stress–testing framework could be applied to more countries, especially to the emerging markets, where the stress–testing methods are still underdeveloped.

Bibliography

[1] Aikman, D., P. Alessandri, B. Eklund, P. Gai, S. Kapadia, E. Martin, N. Mora, G. Sterne, & M. Willison (2009): "Funding Liquidity Risk in a Quantitative Model of Systemic Stability." *Working Paper* **372**, Bank of England.

[2] Baboušek, I. & M. Jančar (2005): "Effects of Macroeconomic Shocks to the Quality of the Aggregate Loan Portfolio." *CNB Working Paper Series* **1**, Czech national Bank, June.

[3] Barnhill, Jr., T. M., P. Papapanagiotou, & L. Schumacher (2000): "Measuring Integrated Market and Credit Risks in Bank Portfolios: An Application to a Set of Hypothetical Banks Operating in South Africa." *IMF Working Paper* **212**, International Monetary Fund.

[4] Basel Committee on Banking Supervision (BCBS) (2006): "Basel II: International Convergence of Capital Measurement and Capital Standards: A Revised Framework–Comprehensive Version." Bank for International Settlements, June. Available at: http://www.bis.org.

[5] Berkowitz, J. (2000): "A Coherent Framework for Stress–Testing." *Journal of Risk* **2**: pp. 1–11.

[6] Board of Governors of the Federal Reserve System (Fed) (2009a): "The Supervisory Capital Assessment Program: Design and Implementation." Federal Reserve System. Available at: http://www.federalreserve.gov.

[7] Board of Governors of the Federal Reserve System (Fed) (2009b): "The Supervisory Capital Assessment Program: Overview of Results." Federal Reserve System. Available at: http://www.federalreserve.gov.

[8] Borio, C., C. Furfine, & P. Lowe (2001): "Procyclicality of the Financial System and Financial Stability Issues and Policy Options." *BIS Papers* **1**, Bank for International Settlements.

[9] Boss, M. (2002): "A Macroeconomic Credit Risk Model for Stress Testing the Austrian Credit Portfolio." *Financial Stability Report* **4**: pp. 64–82, Oesterreichische Nationalbank.

[10] Boss, M., G. Krenn, J. Pann, C. Puhr, & M. Summer (2006): "Systemic Risk Monitor: A Model for Systemic Risk Analysis and Stress Testing of Banking Systems." *Financial Stability Report* **11**: pp. 83–95, Oesterreichische Nationalbank.

[11] Boss, M., G. Fenz, J. Pann, C. Puhr, M. Schneider, & E. Ubl (2009): "Modeling Credit Risk through the Austrian Business Cycle: An Update of the OeNB Model." *Financial Stability Report* **17**: pp. 85–101, Oesterreichische Nationalbank.

[12] Business Monitor International (BMI) (2006): "Privatisation Back on Track Though Delays Expected." *Political Risk Analysis*, Emerging Europe Monitor, October. Available at: http://www.emergingeuropemonitor.com.

[13] Business Monitor International (BMI) (2010): "Macroeconomic Forecast Serbia." *Macroeconomic Forecasts*, Emerging Europe Monitor, October. Available at: http://www.emergingeuropemonitor.com.

[14] Business Monitor International (BMI) (2011): "Macroeconomic Forecast Croatia." *Macroeconomic Forecasts*, Emerging Europe Monitor, January. Available at: http://www.emergingeuropemonitor.com.

[15] Centre for Strategic Economic Studies "Vojvodina CESS" (Vojvodina CESS) & Institut für Höhere Studien Vienna (IHS) (2011): "Economic Forecast for Serbia 2011 and 2012: Recovery Underway, but Challenges for Economic Policy Remain Topical." Centre for Strategic Economic Studies "Vojvodina CESS", published on 22/02/2011. Available at: http://www.vojvodina-cess.org.

[16] Committee of European Banking Supervisors (CEBS) (2009a): "Consultation Paper on Liquidity Buffers & Survival Periods." *CEBS Consultation Paper* **28**, Committee of European Banking Supervisors.

[17] Committee of European Banking Supervisors (CEBS) (2009b): "CEBS Guidelines on Stress Testing." *CEBS Consultation Paper* **32**, Committee of European Banking Supervisors.

[18] Committee of European Banking Supervisors (CEBS) (2010): "Aggregate Outcome of the 2010 EU Wide Stress Test Exercise Coordinated by CEBS in Cooperation with the ECB." *CEBS Summary Report*, Committee of European Banking Supervisors.

[19] Consensus Economics (2010a): "A Digest of Economic Forecasts." Eastern Europe Consensus Forecasts, May. Available at: http://www.consensuseconomics.com.

[20] Consensus Economics (2010b): "A Digest of International Economic Forecasts." Consensus Forecasts, June. Available at: http://www.consensuseconomics.com.

[21] Croatian National Bank (CNB) (2005a): "Banks Bulletin." *Banks Bulletin* **10**, Croatian National Bank. Available at: http://www.hnb.hr.

[22] Croatian National Bank (CNB) (2005b): "Banks Bulletin." *Banks Bulletin* **11**, Croatian National Bank. Available at: http://www.hnb.hr.

[23] Croatian National Bank (CNB) (2007): "Banks Bulletin." *Banks Bulletin* **14**, Croatian National Bank. Available at: http://www.hnb.hr.

[24] Croatian National Bank (CNB) (2009): "Financial Stability." *Financial Stability Report* **3**, Croatian National Bank. Available at: http://www.hnb.hr.

[25] Čihák, M. (2007): "Introduction to Applied Stress Testing." *IMF Working Paper* **07/59**, International Monetary Fund.

[26] De Bandt, O. & V. Oung (2004): "Assessment of "Stress Tests" Conducted on the French Banking System." *Financial Stability Review* **5**: pp. 55–72, Banque de France.

[27] Drehmann, M. (2005): "A Market Based Macro Stress Test for the Corporate Credit Exposures of UK Banks." Available at: http://www.bis.org/bcbs/events/rtf05Drehmann.pdf.

[28] Drehmann, M. (2008): "Stress tests: Objectives, Challenges and Modelling Choices." *Economic Review* **2**: pp. 60–91.

[29] Drehmann, M., S. Sorensen, & M. Stringa (2008): 'The Integrated Impact of Credit and Interest Rate Risk on Banks: An Economic Value and Capital Adequacy Perspective." *Working Paper* **339**, Bank of England.

[30] European Central Bank (ECB) (2010a): "EU stress–test Exercise. Key Messages on Methodological Issues." European Central Bank. Available at: http://www.ecb.int.

[31] European Central Bank (ECB) (2010b): "EU Stress–test Exercise. Technical Note on the Macroeconomic Scenarios and Reference Risk Parameters." European Central Bank. Available at: http://www.ecb.int.

[32] European Central Bank (ECB) (2010c): "Financial Stability Challenges in EU Candidate Countries–Financial Systems in the Aftermath of the Global Crisis." *ECB Occasional Paper* **115**, European Central Bank.

[33] Evjen, S., A. J. Lund, K. H. Morka, K. B. Nordal, & I. Svendsen (2005): "Monetary and Financial Stability in Norway: What Can We Learn from Macroeconomic Stress Tests?." *BIS Papers* **22**: pp. 409–430.

[34] Hamerle, A., T. Liebig, & H. Scheule (2004): "Forecasting Credit Portfolio Risk." *Discussion Paper Series 2: Banking and Financial Supervision* **1**, Deutsche Bundesbank.

[35] Hoggarth, G. & J. Whitley (2003): "Assessing the Strength of UK Banks Through Macroeconomic Stress Tests." *Bank of England Financial Stability Review, June*: pp. 91–103.

[36] International Monetary Fund (IMF) & World Bank (WB) (2003): "Analytical Tools of the FSAP." Background paper prepared for March 14, 2003 IMF Executive Board meeting, International Monetary Fund. Available at: http://www.imf.org.

[37] International Monetary Fund (IMF) (2006): "Financial Soundness Indicators: Compilation Guide." International Monetary Fund. Available at: http://www.imf.org.

[38] Jakubík, P. (2007): "Macroeconomic Environment and Credit Risk." *Czech Journal of Economics and Finance* **57(1–2)**: pp. 41–59.

[39] Jakubík, P. & C. Schmieder (2008): "Stress Testing Credit Risk: Comparison of the Czech Republic and Germany." *FSI Award 2008 Winning Paper*, Financial Stability Institute, Bank for International Settlements.

[40] Jakubík, P. & G. Sutton (2011): "Thoughts on the Proper Design of Macro Stress Tests." *Macroprudential Regulation and Policy, BIS Working Papers*, Bank for International Settlements, forthcoming.

[41] Jokivuolle, E., K. Virolainen, & O. Vähämaa (2008): "Macro–Model–Based Stress Testing of Basel II Capital Requirements." *Bank of Finland Research Discussion Paper* **17**, Bank of Finland.

[42] Kalirai, H. & M. Scheicher (2002): "Macroeconomic Stress Testing: Preliminary Evidence for Austria." *Financial Stability Report* **3**, Oesterreichische Nationalbank.

[43] Mejstřík, M., M. Pečená, & P. Teplý (2008): "Basic Principles of Banking." Prague, Charles University.

[44] Merton, R. C. (1974): "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." *Journal of Finance* **29(2)**: pp. 449–470.

[45] National Bank of Serbia (NBS) (2008): "Banking Supervision: Fourth Quarter Report 2008." National Bank of Serbia. Available at: http://www.nbs.rs.

[46] National Bank of Serbia (NBS) (2011): "Decision on the Classification of Bank Balance Sheet Assets and Off–balance Sheet Items." *"RS Official Gazette", Nos.129/2007, 63/2008, 104/2009 and 30/2010*, National Bank of Serbia, April. Available at: http://www.nbs.rs.

[47] Pesaran, M. H., T. Schuermann, B–J. Treutler, & S. M. Weiner (2006): "Macroeconomic Dynamics and Credit Risk: A Global Perspective." *Journal of Money, Credit and Banking* **38(5)**: pp. 1211–1262.

[48] Pesola, J. (2005): "Banking Fragility and Distress: An Econometric Study of Macroeconomic Determinants." *Bank of Finland Research Discussion Papers* **13**, Bank of Finland.

[49] Peura, S. & E. Jokivuolle (2003): "Simulation–based Stress Testing of Banks' Regulatory Capital Adequacy." *Bank of Finland Discussion Papers* **4**, Bank of Finland.

[50] Sahajwala, R. & P. Van den Bergh (2000): "Supervisory Risk Assessment and Early Warning Systems." *Basel Committee on Banking Supervision Working Papers* **4**, Bank for International Settlements.

[51] Sorge, M. (2004): "Stress–testing Financial Systems: An Overview of Current Methodologies." *Monetary and Economic Department, BIS Working Papers* **165**, Bank for International Settlements.

[52] Sorge, M. & K. Virolainen (2006): "A Comparative Analysis of Macro Stress–Testing Methodologies with Application to Finland." *Journal of Financial Stability* **2**: pp. 113–151.

[53] Tportal.hr (2009): "Ukida se HFP i Zakon o privatizaciji." Published on 10/02/2009. Available at: http://www.tportal.hr/vijesti.

[54] Van den End, J. W., M. Hoeberichts, & M. Tabbae (2006): "Modelling Scenario Analysis and Macro Stress–testing." *DNB Working Paper* **119**, De Nederlandsche Bank.

[55] Virolainen, K. (2004): "Macro Stress Testing with a Macroeconomic Credit Risk Model for Finland." *Discussion Paper* **12**, Bank of Finland.

[56] Wilson, T. C. (1997a): "Portfolio Credit Risk I." *Risk Magazine* **10(9)**: pp. 111–117.

[57] Wilson, T. C. (1997b): "Portfolio Credit Risk II." *Risk Magazine* **10(10)**: pp. 56–61.

Appendix A

Financial Soundness Indicators

Table A.1: Financial Soundness Indicators–Core set

Capital adequacy	Regulatory capital to risk–weighted assets Regulatory Tier 1 capital to risk–weighted assets Nonperforming loans net of provisions to capital
Asset quality	Nonperforming loans to total gross loans Sectoral distribution of loans to total loans
Earnings and profitability	Return on assets Return on equity Interest margin to gross income Non–interest expenses to gross income
Liquidity	Liquid assets to total assets (liquid asset ratio) Liquid assets to short–term liabilities
Sensitivity to market risk	Net open position in foreign exchange to capital

Source: IMF, http://www.imf.org/external/np/sta/fsi/eng/fsi.htm.

Table A.2: Financial Soundness Indicators–Encouraged set

Deposit–takers	Capital to assets Large exposures to capital Geographical distribution of loans to total loans Gross asset position in financial derivatives to capital Gross liability position in financial derivatives to capital Trading income to total income Personnel expenses to noninterest expenses Spread between reference lending and deposit rates Spread between highest and lowest interbank rate Customer deposits to total (non–interbank) loans Foreign–currency–denominated loans to total loans Foreign–currency–denominated liabilities to total liabilities Net open position in equities to capital
Other financial corporations	Assets to total financial system assets Assets to GDP
Non–financial corporations sector	Total debt to equity Return on equity Earnings to interest and principal expenses Net foreign exchange exposure to equity Number of applications for protection from creditors
Households	Household debt to GDP Household debt service and principal payments to income
Market liquidity	Average bid–ask spread in the securities market Average daily turnover ratio in the securities market
Real estate markets	Residential real estate prices Commercial real estate prices Residential real estate loans to total loans Commercial real estate loans to total loans

Source: IMF, http://www.imf.org/external/np/sta/fsi/eng/fsi.htm.

Appendix B

Additional Specifications to the Credit Risk Models

Table B.1: Correlation coefficients for the macroeconomic variables in Serbia.

5% critical value (two–tailed) = 0.3809 for n = 27
(using the observations Q1 2004–Q3 2010)

g_srb	*p*	*u*	*ind*	*er_n*	
1.0000	0.3541	−0.0389	0.7037	0.2859	*g_srb*
	1.0000	0.3675	0.2655	−0.1048	*p*
		1.0000	0.0226	0.1245	*u*
			1.0000	0.2996	*ind*
				1.0000	*er_n*

er_r	*er_usd*	*er_eur*	*i*	*r*	*g_eu*	
0.2568	−0.4979	−0.3662	0.1008	0.0486	0.5831	*g_srb*
0.1349	0.1384	0.0049	0.3020	0.1247	0.1811	*p*
0.3448	0.3981	0.0563	−0.1321	0.1635	0.3848	*u*
0.1987	−0.4922	−0.2267	−0.1068	0.0083	0.6705	*ind*
0.9233	−0.6679	−0.8554	−0.2975	0.2573	0.5761	*er_n*
1.0000	−0.5105	−0.8138	−0.2375	0.3191	0.5382	*er_r*
	1.0000	0.7822	−0.0333	−0.1737	−0.2931	*er_usd*
		1.0000	−0.0453	−0.2295	−0.3028	*er_eur*
			1.0000	0.2115	−0.3869	*i*
				1.0000	0.1768	*r*
					1.0000	*g_eu*

Source: Author's computations. Annotations: *g_srb* and *g_eu* are GDP growths in Serbia and the EU 15, *p* is inflation (PPI), *u* is unemployment rate growth, *ind* is industrial production growth, *i* and *r* are nominal and real interest rate growths, *er_n*, *er_r*, *er_usd* and *er_eur* are growths in nominal and real effective exchange rates and in RSD/USD and RSD/EUR exchange rates. All variables are expressed in terms of the growth rates. The higher the correlation coefficient for the two variables in absolute value, the greater the correlation among these variables.

Table B.2: Correlation coefficients for the macroeconomic variables in Croatia–Part 1.

5% critical value (two–tailed) = 0.2973 for n = 44
(using the observations Q1 2000–Q4 2010)

g_hr	*g_eu*	*p*	*u*	*er_n*	*er_r*	*er_eur*	
1.000	0.593	0.133	−0.531	−0.402	0.259	−0.163	*g_hr*
	1.000	−0.115	0.048	−0.019	0.230	−0.304	*g_eu*
		1.000	−0.199	−0.103	−0.250	−0.203	*p*
			1.000	0.616	−0.113	0.109	*u*
				1.000	0.318	0.578	*er_n*
					1.000	0.161	*er_r*
						1.000	*er_eur*

er_usd	*i*	*i_st_cp*	*i_st_hh*	*i_lt_cp*	*i_lt_hh*	*r*	
−0.473	−0.281	−0.245	−0.500	−0.220	−0.523	−0.582	*g_hr*
−0.008	−0.298	−0.371	−0.265	−0.510	−0.569	−0.377	*g_eu*
0.126	−0.226	−0.178	0.140	0.328	0.023	−0.431	*p*
0.606	−0.231	−0.347	0.251	−0.239	0.214	0.164	*u*
0.582	−0.208	−0.202	0.271	0.177	0.137	0.108	*er_n*
0.073	−0.153	−0.103	−0.308	−0.020	−0.135	−0.205	*er_r*
−0.071	0.039	0.157	0.221	0.315	0.068	0.156	*er_eur*
1.000	−0.256	−0.283	0.105	0.051	0.261	0.195	*er_usd*
	1.000	0.940	−0.075	0.178	0.311	0.621	*i*
		1.000	−0.110	0.284	0.282	0.615	*i_st_cp*
			1.000	0.391	0.317	0.133	*i_st_hh*
				1.000	0.485	0.160	*i_lt_cp*
					1.000	0.385	*i_lt_hh*
						1.000	*r*

Source: Author's computations. Annotations: *g_hr* and *g_eu* are GDP growths in Croatia and the EU 15, *p* is inflation (CPI), *u* is unemployment rate growth, *er_n*, *er_r*, *er_usd* and *er_eur* are growths in nominal and real effective exchange rates and in RSD/USD and RSD/EUR exchange rates, *i_st_cp*, *i_st_hh*, *i_lt_cp* and *i_lt_hh* are nominal lending interest rates on short term and long term credits for corporates and households, and *i* and *r* are nominal and real interest rates. All variables are expressed in terms of the growth rates. The higher the correlation coefficient for two variables in absolute value, the greater the correlation among these variables.

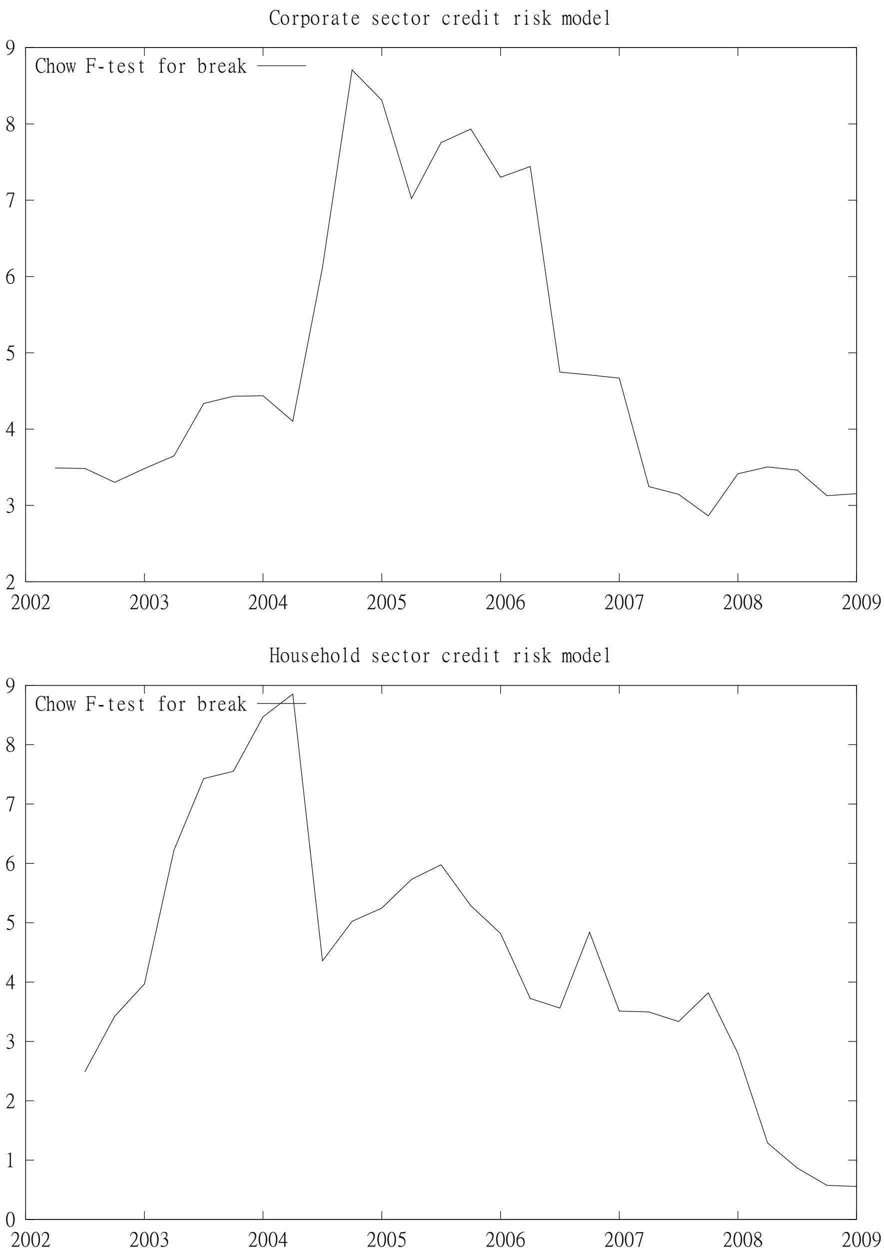
Table B.3: Correlation coefficients for the macroeconomic variables in Croatia–Part 2.

5% critical value (two–tailed) = 0.2973 for n = 44
(using the observations Q1 2000–Q4 2010)

r_st_cp	*r_st_hh*	*r_lt_cp*	*r_lt_hh*	*ir_spread*	*y_disp*	*w_real*	
0.340	−0.665	0.274	−0.664	−0.280	0.672	0.071	*g_hr*
0.245	−0.338	0.166	−0.497	−0.331	0.619	−0.044	*g_eu*
−0.008	−0.488	−0.006	−0.335	−0.352	0.352	−0.191	*p*
−0.099	0.350	−0.124	0.271	−0.115	−0.029	−0.010	*u*
−0.099	0.285	−0.033	0.214	−0.146	0.089	−0.017	*er_n*
0.214	−0.215	0.195	−0.234	0.000	0.018	−0.209	*er_r*
−0.043	0.245	0.008	0.193	−0.016	−0.058	0.170	*er_eur*
−0.221	0.306	−0.155	0.350	−0.145	0.035	0.113	*er_usd*
−0.097	0.278	−0.142	0.401	0.637	−0.409	0.189	*i*
−0.139	0.284	−0.173	0.422	0.494	−0.444	0.218	*i_st_cp*
−0.221	0.428	−0.135	0.281	−0.037	−0.225	−0.092	*i_st_hh*
−0.185	0.158	−0.083	0.291	0.244	−0.138	0.031	*i_lt_cp*
−0.181	0.373	−0.102	0.573	0.384	−0.351	0.141	*i_lt_hh*
−0.602	0.874	−0.567	0.925	0.510	−0.496	0.436	*r*
1.000	−0.517	0.981	−0.612	−0.067	0.206	−0.139	*r_st_cp*
	1.000	−0.431	0.914	0.308	−0.472	0.406	*r_st_hh*
		1.000	−0.519	−0.075	0.180	−0.087	*r_lt_cp*
			1.000	0.392	−0.489	0.448	*r_lt_hh*
				1.000	−0.407	0.053	*ir_spread*
					1.000	0.228	*y_disp*
						1.000	*w_real*

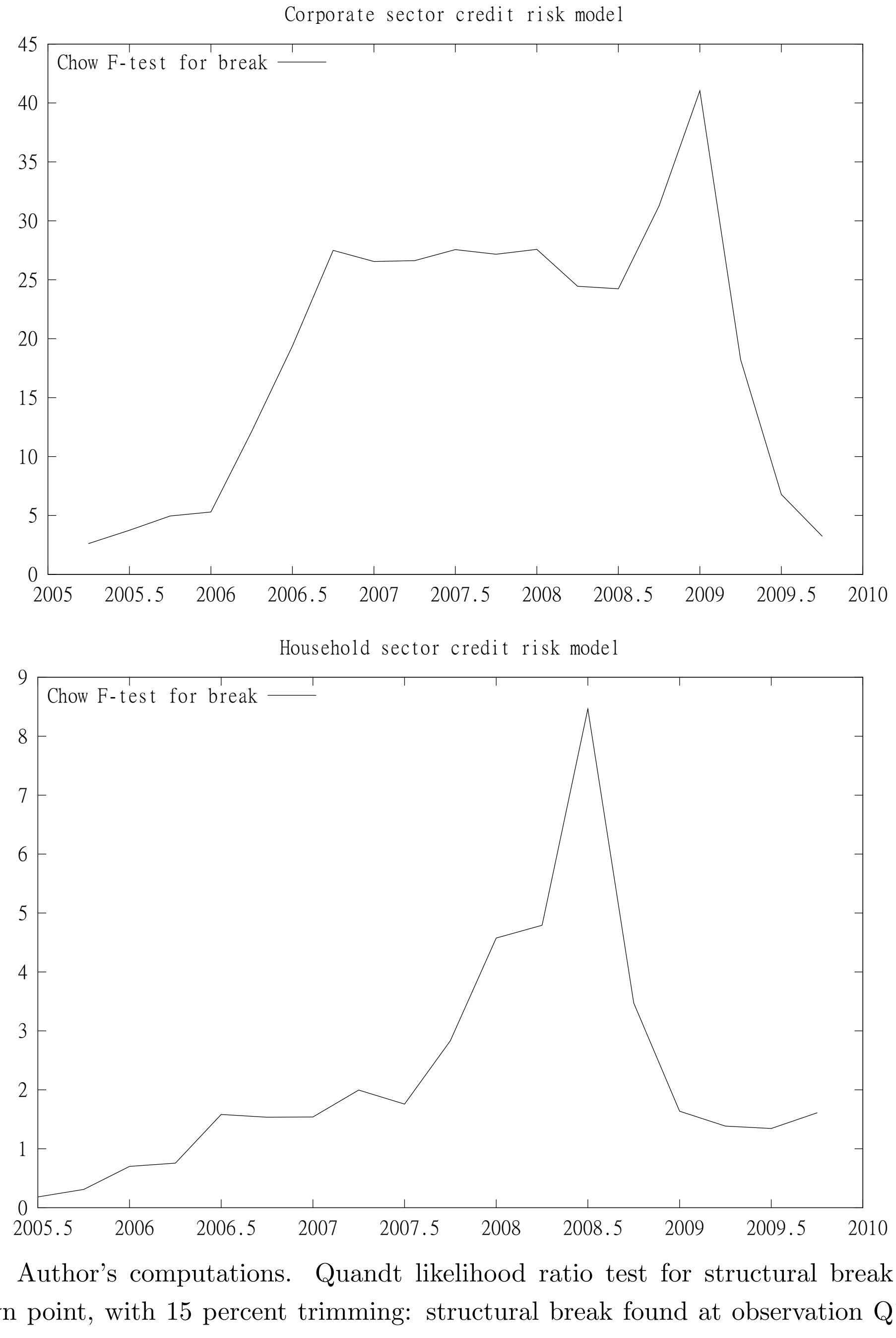
Source: Author's computations. Annotations: *r_st_cp*, *r_st_hh*, *r_lt_cp* and*r_lt_hh* are real lending interest rates on short term and long term credits for corporates and households, *ir_spread* is spread between interest rates on credits and deposits, *y_disp* is disposable income, and *w_real* is real wage. All variables are expressed in terms of the growth rates. The higher the correlation coefficient for two variables in absolute value, the greater the correlation among these variables.

Figure B.1: Chow's F–test for the structural break at an unknown point for Croatia.



Source: Author's computations. Quandt likelihood ratio test for structural break at an unknown point, with 15 percent trimming: structural break found at observation Q4 2004 and Q3 2005 for corporate's model and at Q3 2004 and Q4 2006 for household's model, both significant at the 1% level.

Figure B.2: Chow's F–test for the structural break at an unknown point for Serbia.



Source: Author's computations. Quandt likelihood ratio test for structural break at an unknown point, with 15 percent trimming: structural break found at observation Q1 2009 for corporate's model and at Q3 2008 for household's model, both significant at the 1% level.

Table B.4: Tests for the assumptions of the OLS model–results for the corporate sector credit risk model in Croatia and Serbia.

Model for Croatia	Test	Null hypothesis	P–value
Normality of residuals	Shapiro–Wilk	Normally distributed error	0.9725
Homoscedasticity	White's	No heteroscedasticity	0.6986
Autocorrelation	LMF	No autocorrelation	0.2621
Model for Serbia	Test	Null hypothesis	P–value
Normality of residuals	Shapiro–Wilk	Normally distributed error	0.5525
Homoscedasticity	White's	No heteroscedasticity	0.2366
Autocorrelation	LMF	No autocorrelation	0.3529

Source: Author's computations.

Table B.5: Tests for the assumptions of the OLS model–results for the household sector credit risk model in Croatia and Serbia.

Model for Croatia	Test	Null hypothesis	P–value
Normality of residuals	Shapiro–Wilk	Normally distributed error	0.0397
Homoscedasticity	White's	No heteroscedasticity	0.7143
Autocorrelation	LMF	No autocorrelation	0.9013
Model for Serbia	Test	Null hypothesis	P–value
Normality of residuals	Shapiro–Wilk	Normally distributed error	0.2150
Homoscedasticity	White's	No heteroscedasticity	0.2560
Autocorrelation	LMF	No autocorrelation	0.2790

Source: Author's computations.

Appendix C

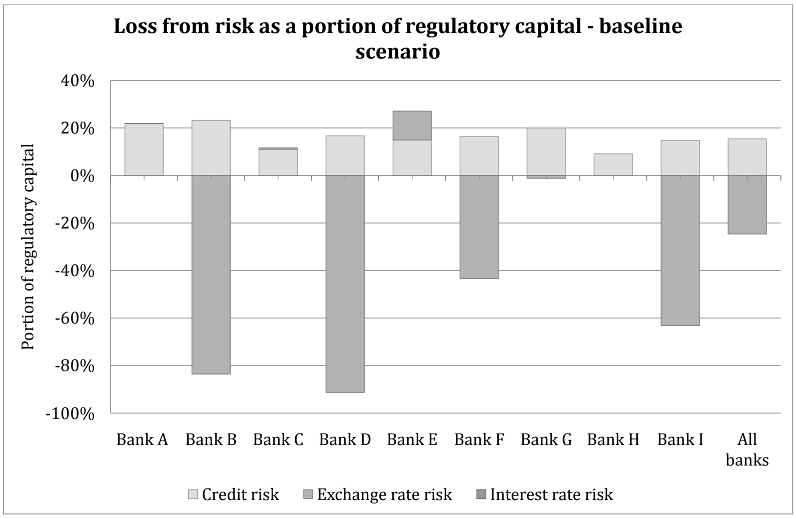
Specification of the Stress–Testing Results

Table C.1: Write–off rates in the Croatian and the Serbian banks.

	Croatia (in %)	Serbia (in %)
Bank A	19.59	12.69
Bank B	34.52	7.20
Bank C	2.43	9.80
Bank D	13.50	28.00
Bank E	0.78	N/A
Bank F	33.91	17.18
Bank G	21.91	44.84
Bank H	27.71	19.31
Bank I	15.45	2.57
Bank J	–	10.64
Average	23.80	18.71

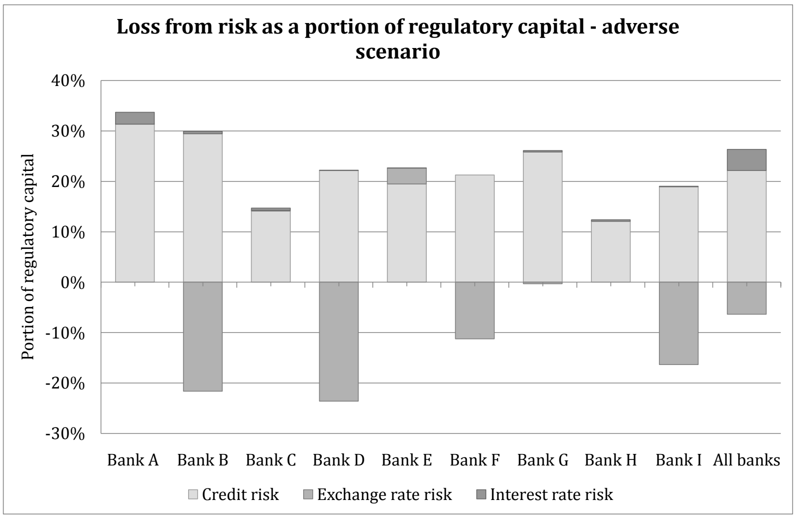
Source: Author's computations. Data are from the individual banks' 2009 financial reports. In the case of Croatia, the write–off rates of Bank C and E were not counted for the average rate due to their relatively low value. Similarly, Bank I was not considered in the Serbian banks' average write–off rate.

Figure C.1: Portion of risks relative to the capital in the baseline scenario for the Croatian banks.



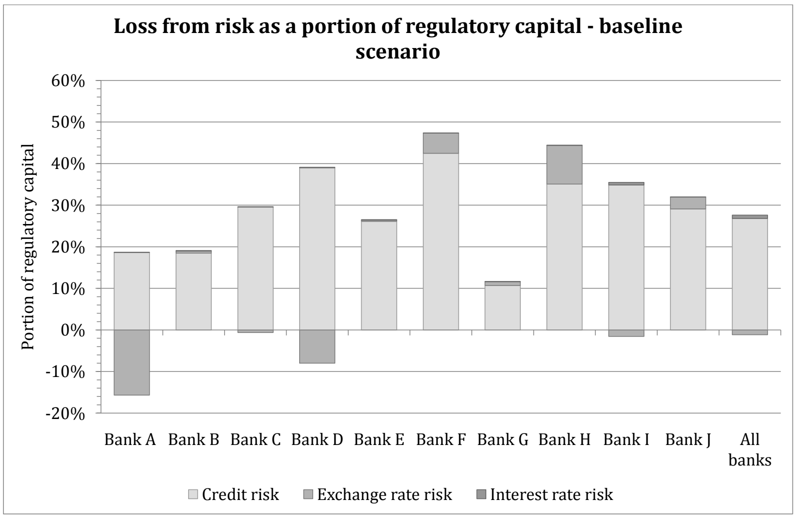
Source: Author's computations.

Figure C.2: Portion of risks relative to the capital in the adverse scenario for the Croatian banks.



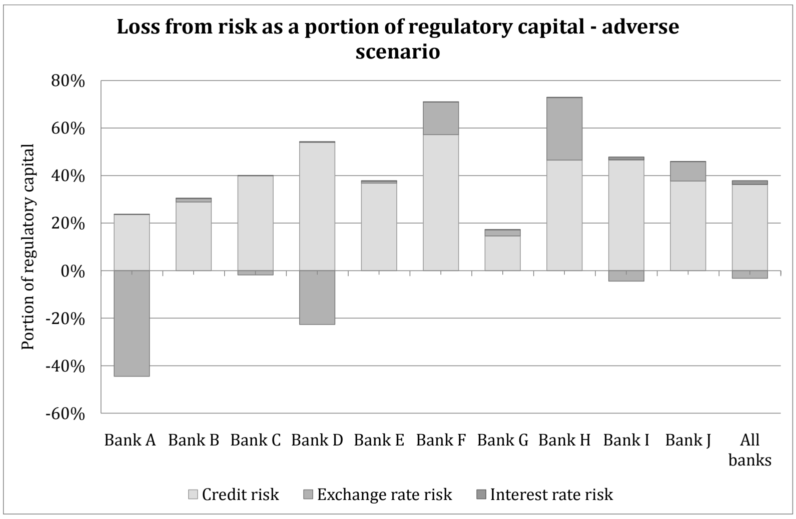
Source: Author's computations.

Figure C.3: Portion of risks relative to the capital in the baseline scenario for the Serbian banks.



Source: Author's computations.

Figure C.4: Portion of risks relative to the capital in the adverse scenario for the Serbian banks.



Source: Author's computations.